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BRIDGE INSPECTION.

By W. S. THOMPSON.

[A paper read before the Engineers' Society of Western Pennsylvania, December 19, 1882.]

I have been asked by members of this society to give them some of the results of my experience as an inspector of bridge material. To oblige them I offer this paper, otherwise I would not have trespassed upon your time, for so much has been written upon every department of bridge building and in every style, that I very much doubt my ability to say anything that is new on the subject.

For convenience I will divide the paper into the following heads: Inspectors, their duties, etc.; Drawings; Tests.

INSPECTORS.

Every shop that buys any article, on receiving it, gives it to some one to examine to see if it is of the proper material, size and quality. This person, it is clear, must have a knowledge of what this article should be and what deviations are allowable from the order for it. You will reply, of course, he must have such knowledge to be able to decide whether the article is suitable. Perhaps so, but I will venture to say, that if you made such an assertion to the foreman or manager of a bridge shop, he would tell you it might be so in a general way, but that it was not always the case in the appointment of those who

are to look after the inspection of bridge material during manufacture. All of them, at least those of the eight or ten shops I have visited recently, as well as some inspectors of my acquaintance, could cite you cases of inspectors who had little or no knowledge of their duties and a very indistinct idea of any sort of manufacture.

What are the requirements for an inspector? As he must decide questions, to solve which require a knowledge more or less great, of strains, designing, drawing, materials and shop work, it is plain he should be familiar with each of these subjects, particularly the last three, as the first two are generally looked after by his employer. His duties bring him in contact with men of all classes, so I may add that he should have some knowledge of business.

Next, what are his duties? He is appointed by his employer to see for him that an agreement is fairly carried out, neither for the purpose of showing his (inspector's) knowledge and authority, nor for the purpose of annoying and delaying the contractor, on the contrary, he should rather assist him if an opportunity offered itself. I do not mean that he is to consider himself in any way an employé of the contractor, but occasions sometimes arise where some such exertion on his part as can reasonably be asked for, will hasten the completion of his employer's work. In such cases it seems to me to be his duty to make that exertion.

At times there will be instances where there is an honest difference of opinion between the inspector and the contractor. Then the former must hear what the latter has to say, but make up his own mind as to what is right, and to hold to that opinion.

Should he think any question that may arise too important for him to decide, he should refer it immediately to his employer and not vascillate nor delay, for by acting in this way he will weary and annoy every one and possibly stop his work.

While any of his work is being done he should make it his duty to be at the shop during the usual office hours, unless he wishes others to decide for him such questions as may arise during his absence. Of course it is not necessary for him to ask permission from the shop authorities when he wishes to be absent, but it is just as well to let them know when and how long he intends to be absent, even if it is only for an afternoon. If nothing else, this is at least a courtesy, and I do not think courtesy is disliked by any one.

The shop is always to supply him with the necessary labor for

handling work. So far as my experience goes, there is never any difficulty about this matter, provided he will be reasonable, except that there are times when the labor cannot be given at the moment it is wanted, the exigencies of the shop not always permitting of it; but, as a rule, I have found that the superintendents and foremen were always willing to help an inspector in every way, as long as the latter was not all for himself and thought of no one else. The shop has to pay for the labor they give him, therefore it is only proper that he should, as much as possible, arrange his work and his time for doing it in a way that will put the shop to as little expense as possible.

He should avoid being distrustful of every one. If he has cause to believe that people are dealing unfairly with him, there are many ways of correcting the matter, or, at least, of relieving himself of the responsibility resulting from such practices.

I have been asked what errors an inspector should look for, etc. It is difficult to answer general questions in a definite manner, but the following may be answer to some I have had asked: Inspection can be superficial or it can be minute, or somewhere between the two. As an instance I may cite the following: An inspector had some 200 pieces about 15′ long and weighing 800 lbs. each to examine. He had to make at least four careful measurements on each piece before he could say they were correct. To do this took him about two hours a day for some four or five weeks. Another inspector went over that same lot, and gave it what he called a thorough inspection; the time he devoted to it, all told, was not over twenty minutes.

In examining work it is hardly possible to say what one thing to look for. Properly speaking, however, and inspector should expect to find everything exactly as it ought to be. With many inspectors riveting is the only matter that is looked after, but there are also, and of equal importance, the size and quality of the material of the different parts; the straightness of the finished piece; the accuracy of the work done upon it, such, for instance, as the size and position of the pin or other holes, or slots, and how these will compare with the other parts with which they are to fit. To sum up in a few words, he must see that the work in all essentials is exactly what the drawing calls for; also, that the material and the work done on it is of the quality called for, for any or all of these may be wrong. Now, he can examine one piece for all these requirements; he can examine all pieces for one thing, as, say riveting; he can see that each piece is correct in every

detail; or, as I have seen done, he may be able to cast a glance over a lot of work and say whether it is right or wrong. Of how this was done I am ignorant, but of one thing I am sure, the opinion as to its condition was not worth much.

There are times when some points in examination may be omitted; judgment and experience must decide when this can be done, but there should be no mere trusting to luck.

The manufacturer is most undoubtedly reponsible for all these things. Inspection does not relieve him from responsibility, nor does his responsibility relieve the inspector. The latter's employer, and the manufacturer also, provided the inspector is competent, think the matter is of so much importance that it is well to have some one to see that the agreement is fairly carried out.

It might not be amiss for the inspector to remember "that he has a reputation to sustain," and that if he is careless, others will likely be so too; also, that in the oft-quoted Tay disaster there was a strong presumptive evidence that the inspectors had neglected their duties, or were ignorant of them.

What allowance can be made in the way of deviation from drawings? For definite answers special cases would here also have to be cited, but generally the following may be made: As to size, shape irons are generally accepted if they are not more than 3 per cent. light. Rods, flat bars, and plates are more easily rolled to a size, therefore they are seldom accepted if not up to that size, though under special circumstances if the light pieces are but comparatively a small proportion of the whole number, the above percentage may be allowed.

Riveted members should be perfectly straight except top chords and inclined posts, which may perhaps be better for having a slight camber, but I often find it necessary to accept posts say 30′ long out of line by $\frac{1}{4}''$. Some few men work closer than this, and it must be acknowledged it is a very vital point. I inspected the material for a very large bridge, every riveted member of which, except one, was perfectly straight; and the error in that one was, if I recollect right, $\frac{1}{4}''$ in 35′.

Punching is not always accurate. If it is not out more than $\frac{1}{4}''$ in 20′ or 30′ it is considered tolerably good work. In the case of angles used as brackets, if, after being riveted on, they are within $\frac{1}{4}''$ of position, it is considered correct. This is usually near enough.

When work of the above kind must be more exact, it should be so

stated, as it calls for an extra class of work. In the width of chords, *i. e.*, the distance apart of side plates or channels, it is usually considered very fair work when they are within 1–16″ of the distance called for, though they must be nearer than this when the side plates are thin, say ¼″.

Top chords and posts should never have their pin holes bored less than the distance apart called for. 1-32″ excess in former and 1-16″ in latter will never do harm, except in some few special designs. Bottom chord and tie bars should, if they vary at all, be less than the length called for. 1-32″ error in these will not be at all serious, provided all the bars are bored to exactly the same length. Struts if bored within 1-16″ are near enough. Shop foremen generally follow the above rules.

In making eye-bars, the smith is allowed ⅜″ over or under length from out to out. In thickness of head he is allowed 1-32″ under or 1-16″ over required thickness, which he sometimes exceeds, but nothing is allowed at the neck, as this is apt to be the weakest part of the bar. In making lateral or other similar rods he is allowed to vary ½″ either way from required length. Other parts must be made closer than this, but smiths rarely forge very closely.

Pins should never be taken if shorter than called for unless their lengths are calculated for washers, and they should be examined closely to see if they are of uniform diameter and not gouged out at the corners or ends.

Rollers may vary a little from required diameter, but they must be all of the same diameter.

Web plates of girders of all classes should be flat, but it is customary to allow the web of large girders to be slightly buckled or dished to the amount of say ⅜″ versed sine to a 6′ chord.

Mills do not always deliver plates perfectly straight. Have them straightened if necessary, but otherwise, when possible, use them as they are, for there is no way of straightening them except by the sledge or drop hammer, neither of which are very good for the iron. For other similar matters I can only refer to common sense and that intuitive knowledge which is the result of experience.

As to inspection at mill. An inspector can only seldom see the actual rolling of his material unless the mill men would roll only to suit his convenience, and even then it would likely be impracticable.

Tension and bending tests of the material can be made at the mill,

though where it is practicable, it is very much better to cut off and test the test pieces at the shop where the material is delivered; this can easily be done by ordering extra pieces or a few pieces of extra length. The inspection of the rolled iron, however, is best done at the shop, for there one can usually see it to better advantage, to say nothing of the fact that the most serious flaws are generally made apparent during manufacture.

My experience has been that the inspection of material at mill, except testing, generally amounts to nothing, for often times they have to load material (at which time the examination is expected to be made) when the inspector cannot be there, or after dark when he cannot see; this is not from any desire to be contrary, for though they are generally hard worked I have found shipping clerks very accommodating, but at an iron mill it requires them to use their wits to keep the yard clear.

Inspectors necessarily lose a great deal of time waiting on others. This is of daily occurrence and cannot be avoided, and such time, as a rule, must be a dead loss.

I have been asked what are the faults of some of the bridge shops. To answer that I fear might be considered as getting personal, though undoubtedly to my thinking all of them have their faults, as, with a few exceptions, they all have one fault in common, perhaps I can speak of that, viz., painting. A bridge-shop painting gang usually consists of a lot of half-grown boys led by a man who has not a very great reputation for either force or thoroughness. The chief idea of the whole crowd is to see how fast they can get over work. It seems to be of no consequence to them whether the whole piece is painted or not, for they sometimes seem to think that it is unnecessary to paint corners or unseen parts, so long as the piece looks as if it was painted. Possibly this may be a result of their being usually hurried, to say nothing of bridge shop paint-work having to be done out of doors and in all sorts of weather. I have no doubt you will smile, but I can assure you that one of the most satisfactory painting gangs I ever came across was led by a boy fourteen years old; most satisfactory, because the boy was a good foreman and saw that his gang did their work faithfully.

DRAWINGS.

The inspector seldom has anything to do with the making of drawings, but he has a great deal to do with them after they are made, and

this generally under unfavorable circumstances, consequently he is much interested in their clearness and fullness of detail.

The bridge draughtsmen should bear in mind that drawings are a species of picture-writing, used to convey to those employed in shops a clear idea of the wishes and intentions of those in charge of designing. Some individuals when writing a letter will write a good, clear, readable hand without crossing their lines, or making fantastic additions to their letters; they also express themselves fully and clearly, consequently one can read their letters rapidly yet have a complete idea of their contents. Others write a cramped, illegible hand, add fantastic scrolls to their letters, omit important words and fail generally to convey their ideas clearly. With writers of this latter style all of us know what a time it requires to find out the exact import of their letter. It is the same with drawings. Some men make their drawings so clear that they can be read at sight; others again draw in such a manner that in attempting to read their drawings you fancy that they tried to make them as much like puzzles as possible. The draughtsmen should also bear in mind that there is a difference between the style of a drawing to be made for shop use and one that is made for a periodical or other similar purpose; also, that when he uses a drawing, he has clean hands, a dry, quiet, and well-lighted place to lay his drawing and weights to keep the corners down, and paper and pencil to supply missing data; but not unfrequently the contrary of this is the case with those in the shop, and particularly so with inspectors, who often times have to hold drawings in high winds and at the same time use rule and callipers, etc. In other words, he should not make sheets too large, nor crowd too much on one sheet, nor put so many lines on top of each other that it is difficult to follow any, nor omit any figures that are required to be known at a given point because they can be found on bill of material or another drawing; thus necessitating a bill of material and a couple of drawings to know, say, what a post end should be, and he should not imagine that pieces of unfaced material are always the exact length called for.

Some may say that the draughtsman's time is expensive, and the foreman would understand this or that. True, the foreman generally can do so, but the foreman does not do the work nor stand over the men doing it, consequently he has to supply the omission of this picture writing to his men, *i. e.*, do draughtsmen's work to the neglect of his own, which, according to an old-fashioned notion, is that he should

look after the quality of the material being used, what sort of work the men were doing, and matters of similar kind, all of which was thought enough for him to do. This latter may be an old-fashioned custom, but I believe it is still adhered to in locomotive and other machine building shops.

Foremen do not always check the drawings to see if they are full and complete; unfortunately this results sometimes in work being spoiled, simply because the drawing did not state what was wanted. True, the foreman could have seen what the draughtsman had omitted if he had been doing the work himself, but his men do not necessarily have the same education and ability as he has, and drawings are as much for the men's use as for any one else.

The errors of draughtsmen, who can be called such, are not, as a rule, in the large matters, but in the small ones, which they think are unimportant and can be left to the shop. This is a fruitful cause of delay and expense, generally small, though not always so, and, in my experience, is one of almost daily occurrence; in fact, I doubt whether I have had a single span under my charge for years on which there could not have been saved a few dollars and upwards, by the draughtsmen paying a little more attention to clearness and those little things which every one knows.

Great accuracy is unnecessary in some of the parts of a bridge which it will be well to remember, as the more accurate the work is required to be the more expensive it will prove, also the fewer the parts the cheaper will be the work. Short pieces of angle iron or any small pieces fastened to a member weigh little but cost greatly.

A drawing should be clear and to the scale, with little or no shading, and when possible should be complete in itself without reference to anything else. Time saved in the drawing room is not always an economy. In making a drawing, a draughtsman should use as few different sizes and lengths of material as possible, for similarity in sizes of pins, bars, rods, and in lengths generally, saves in the cost of workmanship and reduces the chances of error. A theoretical saving of material sometimes necessitates an outlay of several times the amount saved to do the extra work, also, usually, each different form necessitates a different set of rolls for its making, which may cause delay in delivery of material. The designer should have some consideration for what is obtainable, as for instance, a variation of $\frac{1}{2}$ lb. per foot in a 12″ channel only makes a difference in thickness of web of 1-

100″ closer than it is possible to roll, unless there are a large number of same weight.

Plates and bars ordered by 1-32″, or squares and rounds ordered by 1-16″, generally come either full or scant, more likely the former. 1-32″ is looked upon in bridge shops as somewhat of an imaginary quantity, and particularly so to ask it of a blacksmith. My own experience has been that by those working on tools it is considered to mean scant or full of a given 1-16″, but a smith scarcely seems to realize what it is. Tell him a piece is to be so many sixteenths thick and he will come very near it, but ask him to make it so many thirty-seconds thick and you will be lucky if you get it within an eighth. The office says the man should be educated up to this close work, to which the shop replies that the office should be educated up to their wants. I say, that if the office wants such close work, the men are to be found, but they are only to be found in government arsenals and tool making and other establishments that require very close work.

Of late days it seems to be considered important only to be very careful to give distances of rivet spacing. This is no doubt of prime necessity to the layer-off, but not so to the machinist and inspector, the former only wants to know the distances he has to work to, and the one governing point from which he has to start; besides this the inspector usually only cares to know if the number of rivets is correct, and that their spacing is approximately so. In making drawings, distances from centre lines and other governing points should be given, and all parts that are to be planed, bored, or drilled, should be so marked. A hole or slot should always be marked with the size of the pin or tenon that it is to take; and stating what sort of fit is required. Angles are best defined by their base and perpendicular, and it should be remembered that sheared parts are not perfectly straight or smooth; that a punched hole has not parallel sides nor is it always exactly where it ought to be, and that when two or more plates are riveted together their united thickness is generally greater than the sum of their several thicknesses; that right and left pieces or other complications are to be avoided when possible, as they are troublesome and liable to cause errors; and that rivet holes should neither be too large a proportion of the width of a channel flange, nor too near its edge.

As few rivets should be left to be driven in the field as possible, for they are more expensive and less reliable than those driven in the shop. As to the latter, shop hands have every convenience possible, and are

daily occupied in driving rivets, whereas the men in the field have on the other hand almost every inconvenience to contend with, and driving rivets is but a very occasional part of their work.

TESTS.

Looking over the results of a large number of specimen tests of wrought iron made by myself, I find that the results are about the same for bars, rods, plates (edge rolled), angles and channel bars, viz., an ultimate strength of from 50,000 to 53,000 lbs. per square inch, generally 51,000, and an elongation in 6″ of from 16 per cent. to 25 per cent. channel bar webs, and plates ranging chiefly from 16 to 20 per cent. This I think is due very much to the fact that in the test pieces made from these, it was necessary to use a rectangular section. I have tested sheared plates up to 72″x$\frac{3}{8}$″ with the same ultimate strength as the above, but the elongation varying from 9 per cent to 16 per cent.

Bending Tests.—Bars, rods, and channel flanges with few exceptions bent until flat or their ends touched with a curvature, whose diameter varied from one-half to three times thickness of piece, generally one and a half. Plates and channel webs would bend 150 degrees, or until their ends touched with a curve whose diameter ranged from one to four times thickness. All bending pieces were about one foot long, and from 2″ to 3″ wide. Here it may be well to say that bending pieces must not be sheared but planed, and also have their edges well rounded on a grindstone or emery wheel, so as to remove any incipient cracks.

These are tests of such wrought iron, with but few exceptions, as has been used in the work that I have had charge of during the last six years. Of course all will understand, that these tests were applied in line of fibre, as is the ordinary usage.* Where more than this is expected, viz., a strain, crosswise to fibre, it is always specially mentioned, as witness British Admiralty and other specifications The reduction of area has been omitted, as the measurements taken for it are generally unreliable, and as Stoney says, the elongation is much more reliable for any question as to quality of iron.

I have other tests, which are of condemned lots, but presume they would be of no interest, for surely no one is going to try for the worst material he can get. I have had but little to do with cast iron, since

* See table for transverse strength of plates.

testing has become common, but have about 12 or 15 tests from as many heats. In these, the bars 1″ sq., 5′ long, 4′ 6″ between supports, it took from 650 to 700 lbs. resting on dull knife edge at centre to break them, which was a better result than asked for. Of course the foundry hands took good care to place the bar on supports, same side up, as when cast. Such cast iron should only be used in very special cases, for it is certainly much too good to be used in such places as masonry plates, and washers of bridges.

Thus far I eave only tested steel from plates rolled in this country from English Bessemer blooms. I made a large number of tests from these plates, both tension and bending; of the latter there were over 100. The plates ranged in size from 12″x ¼″ to 24″ x ⅜″. The results were very uniform, giving an ultimate strength averaging 70,000 lbs. per square inch, with an average elongation of 30 per cent in 6″. The bending pieces were planed from plate shearings very little broader than the test piece. All these were well rounded on grindstone, heated red hot, and dropped into water of a temperature from 70 to 100 degrees. Nearly all bent 180 degrees flat, some few of those ½″ to ⅝″ cracked at edges when 90 degrees; these latter were then punched within ¼″ of edges without cracking, probably there were invisible edge cracks.

Some of you, no doubt, would like to know what strain full size pieces, just as they go into a bridge, will stand. I have enough of one kind, I think, to satisfy you, viz., of tension members. I have made a few tests of compression pieces which have been published elsewhere.

I will first give you the result of four lots of bars, ranging from 1″ to 2″ diameter, and from 15′ to 25′ long with enlarged ends for thread.

1st lot consisted of 60 iron rods. 14 of these broke in thread, the rest in the body of the bars with 12 to 19 per cent. elongation. All except four stood over 45,000 lbs. per square inch; one of these broke at 35,000 lbs., two at 40,000 lbs., and one at 43,000 lbs. per square inch.

2d lot; 23 rods. 13 broke in screw, the others elongating 12 to 16 per cent. All but one stood over 45,000 lbs.; that one stood 44,000.

The above are only moderately good.

3d lot; 38 rods. 11 broke in screw, the others elongating 13 to 18

per cent. All but seven stood 50,000 lbs. or over; these broke as follows:

1—38,000 lbs. per square inch.
1—42,000 " " " "
1—43,000 " " " "
1—48,000 " " " "
3—49,000 " " " "

4th lot; 30 bars. Two broke in screw. All stood 50,000 lbs. per square inch or over. Elongation of those that broke in bar, was from 10 to 18 per cent. generally 16 per cent; nearly all these broke within 2 feet of end of rod, as did those in the other lots.

Another lot of 20—$1\frac{3}{8}$″ round rods with $1\frac{3}{8}$″ threads (all of course in thread) broke with 37,000 to 40,000 lbs. per square inch of rod.

Before proceeding further, I may as well state here, that the above lots of rods were made by different shops, as were also the eyebars, the test results of which I am about to give you. These I have classed by width of bar, as it will give you as good an idea of the average eyebar as any other classification.

I will first give you the results of tests of some heads made entirely by upsetting, merely saying that they have been given to me, and that I did not see the tests made:

Of 52 bars about $3\frac{1}{2}$″ wide, 22 broke in bar, elongating 7 to 15 per cent., and 30 broke in the head. The ultimate breaking strains seemed too high, consequently I omit them, excepting to say that one broke in the head at 36,000 lbs. per square inch, and two others at 42,500 lbs.

Next I will give you results of tests of eyebars made by piling. With the exception of some 10 or 12 bars, the iron in all of them showed a good fibrous fracture, and with very few exceptions, perhaps six, the heads were proportioned by usual formula.

Of 26 6″ bars, 13 broke in bar with following strains:

5 between 40,000 and 45,000 lbs. per square inch.
6 " 45,000 and 47,000 " " " "
1 " 47,000 and 49,000 " " " "
1 " 49,000 and upwards " " " "

13 broke in head.

11 between 42,000 and 45,000 lbs. per square inch.
2 " 45,000 and 48,000 " " " "

Of 159 5″ bars, 80 broke in bar:

2	between	35,000	and	40,000	lbs.	per	square inch.
10	"	40,000	and	45,000	"	"	" "
17	"	45,000	and	47,000	"	"	" "
27	"	47,000	and	49,000	"	"	" "
24	"	49,000	and	upwards	"	"	" "

79 broke in head—one at 33,000 lbs.

6	between	35,000	and	40,000	lbs.	per	square inch.
36	"	40,000	and	45,000	"	"	" "
22	"	45,000	and	47,000	"	"	" "
11	"	47,000	and	49,000	"	"	" "
3	"	49,000	and	upwards	"	"	" "

Of 46 4″ bars, 26 broke in bar:

3	between	40,000	and	45,000	lbs.	per	square inch.
11	"	47,000	and	49,000	"	"	" "
12	"	49,000	and	upwards	"	"	" "

18 broke in head—one at 37,000 lbs.

10	between	40,000	and	45,000	lbs.	per	square inch.
1	"	45,000	and	47,000	"	"	" "
4	"	47,000	and	49,000	"	"	" "
2	"	49,000	and	upwards	"	"	" "

Of 19 3″ bars, 14 broke in bar:

5	between	45,000	and	47,000	lbs.	per	square inch.
3	"	47,000	and	49,000	"	"	" "
6	"	49,000	and	upwards	"	"	" "

5 broke in head:

1	between	40,000	and	45,000	lbs.	per	square inch.
2	"	47,000	and	49,000	"	"	" "
2	"	49,000	and	upwards	"	"	" "

From the foregoing it seems to me that these results should be called good when

6″	bars	break	at	45,000	lbs.	and upwards.
5″	"	"	"	46,000	"	" "
4″	"	"	"	47,000	"	" "
3″	"	"	"	48,000	"	" "

With an elongation of not less than 10 per cent. nor more than 25, to be measured in not less than 5′. Bars of same rolling even when broken in the body will give differences in elongation; 14 to 16 per

cent, however, is the most common elongation in the above tests. They will also break at different strains; *e. g.* 6″x ¾″ bar broke at 46,800 lbs. per square inch, elongating 12 per cent., when a 6″x1⅛″ bar broke at 49,500 lbs., elongating 15 per cent. One 3x1⅛″ bar broke at 46,000 lbs. per square inch, elongating 17 per cent., another 3x1⅛″ bar broke at 50,000 lbs., elongating 17 per cent., all of which bars, I believe, were rolled from exactly the same stock, and seemed to me to be purely fibrous and without flaw. All who have done much testing, know that results will sometimes vary in test pieces cut from the same piece of iron, to wit, a ¾″ round; but the above variations, seem to be greater than is due to this cause. Some say it is the result of unknown factors in the manufacture; perhaps the effect of heating only a portion of the bar. Is it so?

Some tests made at Watertown on 5″ and 3″ flats 10′ long showed even better than this, but all those bars were rolled specially for the test, had no rough handling, and were not heated or worked on after leaving the rolls. From these and other tests it seems probable that all double-rolled iron bars will, if tested as they leave the rolls, stand from 50,000 to 52,000 lbs. per square inch ultimate strength, with an elongation of 15 to 23 per cent.

Some lay stress upon having a bar break in the shank. I do not think it so essential, though I prefer it, for when the bars have elongated 8 per cent., the bottom chords and ties will have lengthened so much that the bridge will, most likely, fall between its abutments.

I append a table of some tests of eyebars, but wish to give results of three here:

5″x1⅜″ bars had an elastic limit of 27,000 with an ultimate strength of 37,800, broke 6′ from pin, little or no weld. Moral rolling mills do not always pile full length piles. I am very sorry to say, I could show others like this, and testing to destruction is often the only way of discovering this defect.

A 5″ x 1⅛″ bar, 12′ centers had an elastic limit of 33,000 lbs., but broke with 33,500 lbs.

A 5″ x 1 7-16″ bar, 15′ 3″ center, pins 4⅜″, had accidentally been strained beyond its elastic limit, being lengthened thereby ¼″; pinholes had a slight set, say 1-100″. Elastic limit supposed to have taken place at 31,000 lbs. This bar was loaned to me, provided I did not stretch it any more. I put the bar into press with 4⅛″ pins, and applied a strain of 15,000 lbs. per square inch, holding it 5 minutes;

released this, and applied a strain of 20,000 lbs., which was likewise held 5 minutes and released. Finally a strain of 24,500 lbs. was applied for 5 minutes. The pin-holes were then measured; both measured the same, viz., 4 25-64″ transverse to bar, and 4 13-32 in line of bar.

The test of 5″ x 1⅜″ bar is given to show that rolling mills are not always careful, even when paid for extra good iron. That of 5″ x 1 7-16″ bar is given to show that with properly proportioned heads it is not necessary to make pins fit holes so very accurately as is oftentimes required. I do not, however, advocate such a difference as this between pins and pin-holes, but I do not think that it is allowable to make pin-holes 1 32″ larger than pins for diameters of 4, 4½″, and upwards.

Neither 5″ x 1⅜ nor 5″ x 1⅛″ bars gave any intimation of their yielding until their elastic limit had been very nearly reached.

By some, great stress is laid upon applying a proof-strain. I have personally tested several thousand bars and rods of all styles of make, but never found one defect by this proof-strain. Indeed, I have subjected eyebars with visible defects to this strain; and although I have closely watched them, nothing more could be seen than before the bar was under stress.

I have found proof-strains serviceable only with small things that were considered of no importance by the smith.

Whenever the matter is left to me I never use a proof-strain, except where the ends are welded to main body of bar or rod, *i. e.*, finished bar longer than original bar, and then not that I expect it to be of any service, but because I considered it to be a safe plan to examine a weld in every possible way. In place of proof-strains, I should advise, in addition to this, that a number of extra tension pieces should be ordered; and when the whole lot are finished, that as many be chosen as were ordered extra, and then break them; but not till all are finished. The cost will not be great, and I am sure it will have a good effect, for having tried it on a small scale, I have found it to work wonderfully well. So I may say I speak to some extent from experience.

Some railway companies require the modulus of each bar to be taken. In my experience this cannot be done with any accuracy with such appliances as are to be found in shops. To be accurate, the bar ought to be counterbalanced at say every ten feet with movable

weights, so as to eliminate the effects of any sagging which is produced by weight. The pressure-gauges should read accurately and not approximately, and much more time given to it than ordinary shop testing will admit of.

I have tested over 5,000 bars for their moduli, and all the results I have obtained lie between a modulus of 24,000,000 and 30,000,000, or say extensions of .008″ to .01″ per foot for 20,000 lbs. strain.

Generally at any one testing the moduli did not vary more than 3,000,000, of which the equivalent variation in extension would be .001″ per foot.*

In my opinion, even this is greater than it would be if all sources of error were eliminated, for I am inclined to believe, on looking over the tests I have made, that the modulus of the iron (from three different mills) I have tested lies between 26,000,000 to 28,000,000, or the equivalent extensions of from .0092″ to .0086″ per foot to 20,000 lbs., and that the extremes are perhaps even less than here given.

Since writing the foregoing, I find that in Watertown tests of 2510′ bars of two different classes of iron from two different mills, making the lot referred to above, the extension of 21 for 20,000 lbs. strain was within the above limit; the others had the following: .0093″, .0084″, and .008″ per foot. I feel inclined to think that this last ought to be omitted. Taking them as they are for 10,000 lbs. strain per square inch, the variations in bars 30′ long would be .021″, or one and a half sixty-fourths of an inch. In six bars rolled at one mill, the difference of extension for 20,000 lbs. strain was .00048″ per foot, which would be for a 30′ bar with 10,000 lbs. strain, 1-128″ nearly.

As so much testing of bars has been done, perhaps it would be well to state the different ways of making iron eyebars. As to design, the heads may be square, octagonal, circular, pear-shaped, or an oval, made by striking the curves forming eye, from two centres with same radius, and connecting them by tangents. This is done to give a greater proportion of metal back of eye, which, I think, is very judicious, because it makes some allowance for the inaccuracy of the smith, and experience convinces me that it aids very greatly in preventing

* These elongations for moduli were taken between strains of 10,000 lbs. and 20,000 lbs. per sq.″; previous to adopting this method the elongations were taken between strains of zero to 20,000 lbs. per sq.″, and I then obtained as great variations as you can find published, for the unsupported length of bar was the greatest factor in the result.

any deformation to the eye; for when so made, and other proportions as usual, it is extremely rare for them to break at pin-hole. Old English tests, and also those of Chief Engineer Sprague, of the navy, confirm this. Generally the third and last shaped heads are used; they may be either same or greater thickness than the bar, and are connected to the bar by the neck, which is formed of curves of greater or less radii.

As to manufacture:

1st. These heads may be cut out of a rolled plate, or may be forged from billets, and welded to the bar.

2d. The body of the bar may be upset to form the head, without the addition of any extra metal.

3d. Piling pieces are put on end of bar, and the whole partially upset, after which they are pressed or hammered into shape in a die.

4th. Same as last, omitting upsetting.

5th. Is the Springer patent. This is made by bending a piece of iron of proper size and same thickness as a bar, requiring head into somewhat the shape exteriorly of a horse-shoe, with a rectangular slot on the inside. This is slipped on to end of bar, and cover-plates, cut to shape, placed on top and bottom. The whole is then heated, and pressed or hammered into a die, as above.

6th. Is the Kloman bar, with which you are all acquainted.

7th. Is the loop eye, which is formed by bending the bar edgewise around a pin and welding edges together.

No. 1, or welded bars, are nowadays considered inadmissible.

No. 2, or upset bar, makes a very good bar, and the manufacture of it will probably be improved, but I am inclined to think it would be better if they used a little piling.

Nos. 3 and 4, or piled head, is the one in most general use, and makes a very good head; but care should be taken to keep the diameter of the eye and radius of neck as small as possible, the difficulty of manufacture increasing with diameter of eye, and the bar should not be too thin to hold its heat, nor should the head be piled crosswise.

5th. The Springer bar gives any desired latitude to size of head. All bars of this make that I have seen tested broke entirely clear of the head, except one, which broke at pin-hole at 49,600 lbs., the head having an excess of only 31 per cent. I have broken four heads longitudinally and transversely, all of which showed solid welding.

6th, or Kloman. This makes a very good bar; but the only tests I

have of these were made on bars Mr. Kloman tested for his private use.

The 7th, if made by a good smith, will, I believe, always break in body of bar.

For steel bars heads are designed after same pattern as those of iron, but with them welding or piling is not permissible, so that either a Kloman head or one made by upsetting is here necessary. The Edge Moor Iron Co. has a plant for upsetting steel bars. At the time I examined it I was fully convinced that the process could not fail to make a good head; I have since been told that all that had been tested broke near centre of bar when properly annealed—*i. e.*, whole length at one time; if only annealed at ends, they broke near where effects of annealing ceased.

The annealing of steel eyebars appears from tests to be a matter of considerable importance.

As to round and square rods, they have eyes and enlarged ends for screws, made after the same modes as eyebars, except that the diameter of the ends of iron bars are sometimes increased by piling or splitting the bar, putting in a wedge, and welding all up.

I intended to have embraced specifications as a part of my subject, but I have detained you long enough. I hope some one will give us a paper on this subject, and in it show that some specifications ask for impossibilities; that others have costly manufacturing requirements, which are omitted after the work is let, and that much also could be done to relieve the labor of estimating by adopting a standard column formula and by adopting rolling loads at so much per foot, or, at least, using standard engines.

Results of Tests of Eye Bars with Heads made with Piling Pieces—Tests made with Hydraulic Machines fitted with Mercury Gauges. Bars varied in Length from 10′–0″ to 25′–0″.

Size of Bar in inches.	Elastic Limit in Pounds per square inch.	Breaking Strain in Pounds per sq. inch.	Per cent. of Elongation.	Distance of Fracture from nearest Pin Centre in inches.	REMARKS.
6x1⅝	24,500	43,700	11	.....	Broke at head.
6x ¾	30,000	47,000	13	.....	" " "
6x1	27,000	40,500	5	12	Granular.
6x1	27,000	42,200	7	24	"
6x1 9/16	25,600	45,800	21	32	Fibrous.
6x1	29,900	46,500	13	17	"
6x ¾	30,600	46,800	12	15	"
6x1 9/16	28,800	47,400	15	32	"
6x1⅝	28,000	49,500	15	21	"
5x1⅝	28,300	43,500	10	.....	Broke at head.
5x1	31,000	46,000	8·5	.....	" " "
5x1	28,000	47,000	9	.....	" " "
5x1 9/16	29,000	48,700	11·5	.....	" " "
5x1 7/16	25,800	37,000	4	24	Granular.
5x1⅜	26,500	37,800	5	66	Fibrous. Bar not welded.
5x1	31,000	42,000	4	.....	In bar, distance and character of fracture not noted.
5x1	28,000	45,000	14	85	Fibrous.
5x1⅜	28,000	46,500	9·5	24	"
5x1	29,000	49,000	16	24	"
5x1½	30,000	49,000	14	20	"
5x1	30,000	50,000	16	20	"

Results of Tests of Eye Bars, Etc., Continued.

Size of Bar in inches.	Elastic Limit in Pounds per square inch.	Breaking Strain in Pounds per sq. inch.	Per cent. of Elongation.	Distance of Fracture from nearest Pin Centre in inches.	REMARKS.
5x1½	30,000	50,000	16	20	Fibrous.
5x1⅜	30,400	51,000	15·2	60	"
5x1	31,000	51,000	15	136	"
4x1¼	28,000	43,000	10	.....	Broke at head.
4x1⅜	30,000	48,690	12	.....	" " "
4x1⅛	29,000	45,000	13	80	Fibrous.
4x1⅜	27,300	47,500	18	21	"
4x1¼	29,600	47,800	15·5	26	"
4x ⅞	34,000	48,000	6·8	24	Granular.
4x1¼	27,400	48,000	13·3	16	Fibrous.
4x1⅛	28,300	48,500	16·6	18	"
4x1⅜	28,700	48,700	14	20	"
4x1	30,500	49,200	13	12	"
4x1¼	30,000	49,600	16	13	"
4x ⅞	32,000	49,800	15	24	"
4x ⅞	29,700	50,000	16	20	"
4x1	31,800	50,000	15	.....	" Broke in bar, position of fracture not noted.
3x1⅛	30,000	46,000	17	24	Fibrous.
3x ⅞	30,600	46,400	14	24	" Broke in bar position of fracture not noted.
3x1	.....	50,000	12	.....	Fibrous.
3x1⅛	31,700	50,000	17	22	"
3x1¼	32,000	50,000	15·3	22	"

Results of Tests of Iron Plates—Tension Tests made with Lever Machines.

	Lengthways.					Crossways.			
	Thickness in inches.	Ultimate strength per square inch in pounds.	Per cent. elongation.	Elongation measured in inches length.	Bending.	Ultimate strength per square inch in pounds.	Per cent. elongation.	Elongation measured in inches length.	Bending.
A	¼	52,000	20	6	180° flat.	29,500	2.2	4	20° to 3″ circle.
"	⅜	50,500	19	6	180° flat.	31,400	1.5	4	25° to 9″ "
"	½	51,000	24	6		34,300			
"	½	51,000	21	6	180° to 1¾″ circle.	31,500	3	4	25° to 9″ "
"	½	52,000	23	6		33,400	2.5	4	15° to 4″ "
"	⅝	51,000	17	5	Ends touching to ⅝″ circle.	28,900	2	5	25° to 9″ "
B	⅜	50,700	9.4	8	Ends touching to 1″ circle.	36,500	2	3	30° to 3″ "
"	⅜	51,000	9.5	8	Ends touching to 1½″ circle.	36,000	.....	.....	60° to 5″ "
"	½	50,600	13	6					
"	½	51,600	13	6					
"	½	51,700	17	6					
"	⅞	54,000	.....	.....	160° to 2″ circle.	39,000	2.3	3	
"	⅞	50,500	9.2	8	170° to 2″ "	34,400	2	3	40° to 6″ "
"	⅞	51,500	12.7	8	170° to 1″ "	38,000	3	3	
B	⅜	46,400	13	8	180° to 1″ "	31,800	0.6	8	
"	½	50,800	11.7	8	180° to 2″ "	32,600	1	8	
C	¼	53,700	7	10		not given.			
"	½	49,300	6.7	10					
D	¼	47,500	9	10		42,500	2.7	10	
"	¾	47,900	10	10		41,900	3.8	10	
E	⅜ to ⅝	47,700	16.7	10		45,500	11.2	10	

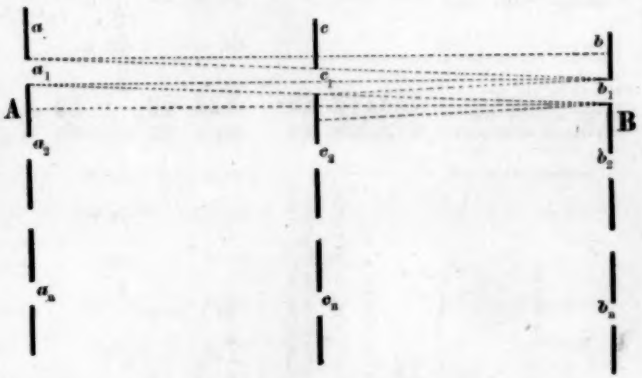
Tests A were from American edge-rolled bridge plate.
" B " " " sheared "
" C " " ordinary English ship plates.

Tests D were from ordinary English boiler plates.
" E " " Yorkshire wrought iron plates.
" C, D, and E are a mean of several tests made by Mr. Kirkaldy.

RADIANT HEAT AN EXCEPTION TO THE SECOND LAW OF THERMO-DYNAMICS.*

By H. T. Eddy, Ph. D.

Since the radiation of heat takes place by propagation through space at a certain finite velocity, and not instantaneously, it is quite possible for occurrences to intervene during the exchange of radiations between two bodies, such as to essentially change the distribution of heat which would otherwise have ultimately taken place.



To make this evident, let us first employ a mechanical analogy. In the accompanying figure, let there be three parallel screens a, b, and c, the latter between the two former, and all three perpendicular to the plane of the paper. Let them be pierced respectively by a series of equidistant apertures $a_1\ a_2\ a_n$, $b_1\ b_2\ b_n$, $c_1\ c_2\ c_n$, situated in the plane of the paper, and let these apertures be so placed that a_1, b_1, c_1, are upon one straight line, not quite at right angles to the screens; then are a_2, b_2, c_2, etc., and a_n, b_n, c_n, upon lines parallel to a_1, b_1, c_1. Now conceive the screens a, b, c, to have a common uniform velocity, u, in the direction from c_2 to c_1. Also, let a series of projectiles be discharged from any fixed position, A, at the left of the screen a, at such instants as to pass the first one through the aperture a_1, the second through a_2, etc.,

* From the Proceedings of the Ohio Mechanics' Institute, May 25, 1882.

and let the direction of discharge be perpendicular to the screens, and the velocity, v, such that each one shall just reach the screen b in time to pass through the first aperture of that screen which crosses its path. Then would the screens a b c in no way interfere with the passage of these projectiles. Let us denote the space at the left of a as the space A, and that at the right of b as the space B. Then, if there be a continuous discharge of projectiles from all points of the space A, only a part of them can pass through the apertures of a. Such, however, as succeed in passing a, will pass b and c also. Again, let a second discharge of projectiles take place from the space B, but directed toward the left perpendicularly to the screens, so that these projectiles move in a precisely opposite direction from those first mentioned. Let the projectiles from B have the common velocity v'. Such of these projectiles as succeed in passing through the apertures of b will impinge on c at points between its apertures, in case c be placed at a proper distance from b. Let the surface of c which faces b be perfectly reflecting, and let the parts between its apertures be either concave, or a series of inclined planes, so directed that each of the projectiles on rebounding will pass back through one of the apertures in b. When the velocity v' of the projectiles is large compared with that of the screens u, the projectiles can be made to return through b very nearly perpendicularly, either by returning each projectile through that aperture from which it started or through some following one.

The paths of the projectiles relative to the screens can be readily found by impressing upon the projectiles, in addition to their velocities v or v', a velocity—u, numerically equal and opposed to that of the screens, while the screens themselves are at rest. The composition of these velocities will give the required relative velocity.

In order to apply the mechanical analogy just considered to the case in hand, let us replace the supposed projectiles by radiations which emanate from warm bodies situated in the spaces A and B, and let the only radiations at first considered be those in a direction perpendicular to the screen.

It is then evident that with such a series of apertures as are represented in the figure, the screens a b c could be given such a velocity u, as, accompanied by reflections from c, would transfer radiations from the body A to B, unaccompanied by a compensating transfer from B to A; and thus the body B would be heated at the expense of A.

Even if radiations at the apertures in a and b be not confined to rays perpendicular to the screens, but take place instead in the manner usual at plane surfaces, it is still evident that the usual interchange of radiations has been effectively interfered with, and that the body B would be heated at the expense of A. In case the radiations from the body B are reflected back through the same apertures from which they started, it is quite unnecessary to have the series of apertures in the screen a at equal distances; it is only necessary that the series of apertures in b and c correspond to those in a. Indeed, each aperture in b can be conceived to be completely surrounded by a concave semicylindrical reflector attached to c, of such a form as to return to b all radiations from it when moving with the velocity u. This can certainly by effected if the apertures in b are mere points, and can be closely approximated to when they are small. Now, if there be in this cylinder a proper aperture for the admission of the normal radiations from A through a, it is evident that the radiations passing through this aperture from B, being oblique, are, when the bodies are of equal temperature, less than those of A passing through the same aperture, according to the well known law of radiations that the intensity is proportional to the cosine of the angle between the ray and the normal to the radiating surface. It is seen that with a sufficiently large value of u, it would be possible to overcome any difference of temperature, however great.

In order to form an estimate of the amount by which the radiation from A to B exceeds that escaping from B through c, let us suppose that the temperatures of A and B are equal, and that the velocity v of the radiations from A and B is the same; and, further, let the screen c be midway between a and b at a distance p from each. Let the problem be to compute the ratio between the radiations which pass through a given aperture, as c_1, from a_1, and from b_1, respectively, on the supposition that the heat radiates from the equal apertures a_1 and b_1, as from plane surfaces, in the usual manner.

Suppose that the linear dimensions of the apertures are infinitesimal compared with p, and let the letters $a_1\ b_1\ c_1$, considered as numerical magnitudes, designate the areas of the apertures $a_1\ b_1\ c_1$ respectively. Let θ be the angle between a ray and the normal to the surface from which it radiates. Let a sphere of radius p be supposed to be described about some point of b_1 as a centre, and let s be the area of that part

of its surface included within the cone of rays passing from the centre to the periphery of the aperture c_1;

$$\text{then } \frac{s}{p^2} = \frac{c_1}{r^2} \cos\theta \tag{1}$$

in which r is the distance passed over by the ray from b to c.

$$\text{Also } p = r\cos\theta \tag{2}$$

$$\text{therefore } s = c_1 \cos^3\theta \tag{3}$$

Now the heat radiated from b_1 is directly proportional to the area b_1, to the area s, and to $\cos\theta$, but inversely proportional to p^2;

$$\text{hence } \frac{b_1 s}{p^2}\cos\theta = \frac{b_1 c_1}{p^2}\cos^4\theta \tag{4}$$

is proportional to the heat radiated from b_1 through c_1.

$$\text{Similarly, } \frac{a_1 c_1}{p^2} \tag{5}$$

is proportional to the heat radiated from a_1 through c_1, since it passes c normally. Now the heat passing from b_1 to c_1 must evidently move in a direction to overtake the aperture c_1, and to do this it must evidently take a direction such that θ is defined by the equation

$$\tan\theta = \frac{2u}{v}, \text{ or } \cos^2\theta = \frac{v^2}{v^2+4u^2} \tag{6}$$

Hence, by comparing expressions (4) and (5), and substituting from (6), it appears that the heat radiated from a_1 through c_1 is greater than that radiated by an equal surface b_1 through c_1, in the ratio of $(v^2+4u^2)^2$ to v^4, in case the temperatures of a_1 and b_1 are equal. If the temperature of a_1 were lower than that of b_1, this ratio would be diminished; but by increasing u, the ratio can still be made to exceed unity, thus confirming the observations previously made. Neither is it essential that the radiations all take place at the same velocity. The reflectors can be arranged for some one velocity, and they will then send back the radiations to B, which have that velocity.

Perhaps the most simple ideal arrangement for effecting the proposed interference with the radiations naturally taking place between two bodies, is to suppose the apertures distributed around the circumferences of equal circles, upon three parallel disks fixed upon a common central axis, so that the plane of the paper in the figure becomes the surface of a circular cylinder, in which case the required velocity u can be given to the apertures by simple rotation. Let us for brevity call such an

arrangement a *radiation syren*, or simply a *syren*, as it slightly resembles in its mechanical details the acoustic instrument called by that name. Now, theoretically, no expenditure of energy is necessary to preserve the uniform velocity of the moving parts of this syren; and once started with a sufficiently high velocity of rotation and proper adjustment of reflectors, it would transfer heat from the body A to B, regardless of their temperatures, provided no radiations are permitted except those perpendicular to the disks, excluding, of course, all radiations to and from all bodies other than A and B. It would also, as before shown, transfer heat from a colder body to a hotter, even though the radiation follow the general law of radiations from plane surfaces.

It is needless to state that the action of the syren, regarded as a possible physical process, is directly at variance with hitherto accepted axioms and conclusions respecting the second law of thermo-dynamics. It is true, we should at first thought be inclined to the belief that the laws of heat should suffer some modification, in case we assume differing rates of propagation not infinite, but we should hardly be prepared to admit the startling conclusions which must flow from such modification, if the physical process just sketched be admitted to be valid; and these I shall now proceed to develop.

I think it may be readily perceived that the axioms of Clausius, upon which he founds the second law, viz., that "heat can not of itself pass from a colder into a hotter body," when applied to radiations, implicitly assumes that the heat is radiated with infinite velocity; for it takes no account of the states of relative rest or motion of the bodies between which heat passes.

The axiom of Thomson, "It is impossible, by means of inanimate material agency, to derive mechanical effect from any portion of matter by cooling it below the temperature of the coldest of surrounding objects," is obnoxious to the same criticism; and, as I have stated elsewhere,* these should not be called *axioms* at all, since we are not in a position to bring sufficient experience to bear upon them to affirm their validity or want of validity. Indeed, if the process of the syren be admitted to be possible, we are now in a position to assert that there exists an unexplained contradiction, which does not permit us to consider them as applicable to radiations of heat propagated at finite velocities.

*Thero-dynamics, New York, 1879.

What, it seems to me, the statements of Clausius and Thomson just quoted, really asserted, was the historical fact that at the date when they were made no one had as yet invented any machine, or discovered any principle on which it was possible to construct a machine, which could successfully accomplish what these said had not been done; and it was further implied that no such machine could probably ever be invented, nor any such principle discovered.

In complete accord with this statement is that of Kirchhoff, made in his lectures upon the Theory of Heat during the summer semester of 1880, in which he said, if correctly reported, that the second law can not be (at present) proved; but it, so far, has never been found in disagreement with experience.

It is well known that Maxwell has proposed a process to accomplish this very object; namely, to transfer heat from a colder to a hotter body, in the following manner: If we suppose minute beings, endowed with senses sufficiently acute, and having a corresponding agility to guard minute openings in the diaphragm separating two portions of the same gas, which openings are only large enough for a single molecule to pass at once, they would be able, without expenditure of energy, to open and close the openings in such a way as to allow each molecule impinging at an opening to pass through or not, as they should choose. If they permitted only those molecules having more than the mean *vis viva* to pass in one direction, and only those having less than the mean to pass in the opposite direction, then the gas in one side of the diaphragm would gain energy at the expense of that on the other side. That this process is actually at present beyond human ability, does not show that we may not at some future time be able to accomplish what Maxwell proposed. If this be admitted, then the conclusions which I shall draw later from the lack of generality in the second law of thermo-dynamics flow to a limited extent from the possibility of this process. But Maxwell's process assumes the kinetic theory of gases as its basis, and stands or falls with it. And if the second law is a necessary ultimate mechanical principle, holding for all bodies great and small, the above consequence of the kinetic theory of gases being in contradiction to the second law, is fatal to the validity of the kinetic theory. But I do not now so regard the second law. I am compelled to regard it as merely an approximation in the case of radiations, and to regard it in general with Maxwell and with Boltzmann,* as merely

*Wien. Sitzb., Bände LXXVI, LXXVIII.

the mean result flowing from the laws of propability, though it had previously seemed to me possible to show it to depend upon fundamental considerations, respecting the nature of heat as a form of energy as was stated in my work previously referred to.

To advert to the consequences which are thus made to flow from the established fact of the finite velocity of radiant heat, we may mention that if the law of the dissipation of energy is no longer to be regarded as of universal validity, it being obviated by the process of the syren, it is just as possible to avail ourselves of the heat stored in cold bodies as in hot ones, and thus to employ the heat of a glacier to drive a steam engine, or to perform other like feats heretofore regarded as impossibilities. When I say it is just as possible, I do not imply that it is now just as practicable, or perhaps, ever will be so. That these observations are just is seen when we reflect that the process of the syren simply heats a given body at the expense of any other, regardless of temperatures, by a method requiring the expenditure of no energy. It thus appears that it is possible to avail ourselves of the heat existing in bodies below the lowest thermometric levels of surrounding objects.

It may be objected that the syren renders a perpetual motion a possibility. That depends upon the definition of perpetual motion which we adopt. In the popular acceptation of that term, the process of the syren, as well as that of Maxwell, would make something near that possible. But when correctly viewed, the process of the syren does not imply the possibility of a perpetual motion, any more than does combustion or using the available energy of any chemical process. It simply proposes to employ the finite amount of energy existing in a given body, in the form of heat, in a given way.

It is admitted by all that heat could—a part of it—be made to do work by parting with some of it to a cooler body. The question is whether this last part, which has been imparted to a cooler body, can be restored or transferred to the warmer body again without the expenditure of energy. Rankine evidently believed such a transfer possible; for, in a paper on the "Reconcentration of the Mechanical Energy of the Universe,"[1] he has supposed it possible to reflect radiations in such a way as to give the universe such differences of temperature as to insure it a new lease of life. Clausius, in his admirable paper on the "Concentration of Rays of Light and heat,"[2] has shown

[1] Philosophical Magazine (4) 4, 358.

[2] Mechanical Theory of Heat, Chapter XII.

the general impossibility of such a reconcentration as Rankine supposed, when the radiating bodies are at rest; nevertheless, no such impossibility may finally appear in case of the actual universe, which is a system of moving bodies.

The law of the dissipation of energy has been applied to the universe at large, and if the consequences which have been drawn from its supposed validity are to be regarded as no longer expressing a necessary law, then we are led to affirm that without a change in the laws of nature, as at present known to us, it is possible for increasing differences of temperature to be caused without the expenditure of energy, however improbable the supposition may be that such is the fact, and however improbable it may be that such differences are actually being caused on a scale sufficient to interfere in any practical way with the progress of the dissipation of energy, as affirmed by Thomson, or check the increase of the entropy of the universe, as stated by Clausius. Still it may be remarked that a large part of the exchange of heat in the universe takes place in the radiant form; and, it seems to me, that it remains to be proved what the fact actually is, and consequently I must regard it as still an open question, as to whether on the whole the available energy of the universe is being dissipated, and its entropy increases or not.

Lest the foregoing remarks should be construed as in any sense undervaluing the splendid discoveries of Clausius, Thomson, and Rankine in the domain of thermo-dynamics, let me disclaim such an interpretation entirely, and say that my only wish is to add, if possible, to the exactness and completeness of those theories, which are among the most important of modern physics.—UNIVERSITY OF CINCINNATI, *April 22, 1882.*

NOTE.—Professor J. Willard Gibbs has suggested to me that we are not at liberty to assume that reflections or radiations taking place at moving surfaces follow the same laws as from surfaces at rest; and that a perfect reflector, moving in a medium through which luminous waves are being propagated, may suffer a resistance which would require the expenditure of as much energy as could be obtained by the proposed process. Admitting for the moment the justness of these observations respecting reflections and radiations from moving surfaces, I shall hope to show, in the first place, that the syren may be so adjusted that no such resistance need be encountered, and in the second place, that it is possi-

ble so to modify the syren that no reflections or radiations need take place from moving surfaces.

In the discussion of the first point, let us consider the case of a ray falling perpendicularly upon a perfect reflector. The only numerical magnitudes susceptible of variation in this radiation are its wave length and amplitude, the velocity being assumed constant and dependent upon the elasticity of the medium. When the reflector moves in its own plane at right angles to the ray, it cannot, apparently, be seriously urged that the reflected ray will have either its wave length or its amplitude changed by the reflection. For, so far as can be seen, the wave length would suffer a change and be shortened only by giving the reflector a motion toward the approaching ray, thus crowding the waves together. Neither would the amplitude be changed, for to do this would require the moving plane to impart tangential impulses to the ether, such as can be compounded with the transverse motions already existing. If such be the tangential action of the moving plane on the ether, we should be led to the apparently inadmissible result, that since a moving plane may impart tangential impulses to the luminferous ether, a disk rotating with sufficient velocity in vacuo would become self-luminous.

It would seem but reasonable, in our present imperfect knowledge of the subject, to conclude that the only resistance which a perfect reflector experiences while moving against a ray is normal to its surface, and to be represented by a normal pressure. Even if this view be not regarded as entirely correct, it may, nevertheless, be confidently affirmed that the tangential must be small compared with the normal resistance, just as a frictional resistance of a gas is small compared with that arising from direct pressure upon a body moving through it. Hence it is seen that in spite of friction, it is possible to make a ray turn a mill whose vanes are perfect reflectors, in the same manner as the wind turns a wind-mill; and the energy expended will in that case be withdrawn from the ray itself. Now the rotating screen c of the syren may be regarded as such a mill, the surfaces of whose vanes may be so inclined as to return radiations coming from B, partly to apertures in front of those from which they emanated, and partly to those behind, so as to exert no force either to accelerate or retard c. Should, however, energy be expended in moving c against the reflected ray, this energy must exist immediately after the reflection in the reflected ray, and be transmitted by it to B. Hence we are led to the following remarkable result: On the hypothesis that radiations cause

pressure at surfaces at which they suffer total reflection, a part of the energy of the radiation may be expended in moving the reflector against a resistence, while the remainder is all reflected to the body from which it emanated. It is to be noticed that this process of the *reflecting mill*, or *mill* as it may be called for brevity, is, if possible, in more pronounced and unequivocal contradiction to the second law than that of the syren. For the latter calls in question the accepted law of mutual exchanges, and the second law as depending upon it; but the former applies to a single body alone, as B, and a moving reflector. For example, let B have no radiations except those through the apertures b; then if that part of its radiations which are not expended in turning c are returned to it, it is possible for the mill c to be turned by radiations from B, until the energy of B is all expended in performing work, thus withdrawing all heat from B, while no heat has been transferred to any other body in the manner required by the second law, and this regardless of the temperature of surrounding objects. It therefore seems to me that the supposition of a pressure at reflecting surfaces is more directly opposed to the second law than that of no pressures.

In regard to the second point mentioned, it seems quite possible to construct a syren such that the reflections in it shall all take place from stationary surfaces, or from those whose velocity differs from zero by less than any assignable quantity. For, let the mean velocity u of the screens be the same as before, but not continuous. Instead, let its motion consist of sudden steps forward, each of which is half the width of an aperture. The possibility of a mechanical arrangement, which could effect this motion without expenditure of energy, with the aid of perfect springs, fly-wheels, detents, etc., to any required degree of approximation, will, I think, be admitted, certainly by any one who can admit that Maxwell's "sorting demon" expends no energy in opening and closing apertures. It will be seen that the reflections all take place from screens at rest (or nearly so) in this modified syren, and that the same transmissions occur through its apertures as have heretofore been supposed to take place. I am not inclined, however, to insist on the special kind of apparatus which I have proposed for rendering sensible the phenomenon which I believe to exist during the time in which radiations are in process of becoming established, as contemplated in the ordinary law of thermal exchanges. The point to which I would emphatically direct attention is, that since radiations

are known to be moving in space apart from ponderable bodies, and subject to reflections, it is possible so to deal with them as to completely alter their destination, and successfully interfere with all results flowing from Prevost's law of Exchanges. It also seems to me that the exactness of the second law of thermo-dynamics depends, as far as radiations are concerned, upon that of this law of exchanges.

Cincinnati, May 18, 1882. H. T. E.

CRANK PINS OF MARINE ENGINES.

By J. H. WHITHAM,
Cadet Engineer, U. S. N.

In compiling appended table, the co-efficient of friction was assumed to be 0·05. The table contains crank-pin data from the modern English and American naval and merchant vessels. In each case the engines were performing well and at full power. The *Miantonomah* is the only exception, and she has not as yet had a fair trial of her machinery, but her crank-pin should run cool, as she has an excessive margin of safety, both as regards the projected area of pin and its pressure and the work of friction per unit of area. Comparing the performances of English and American crank-pins, it is seen that the work of friction and pressure per square inch of projected area for the former exceed those of the latter; also, that no one method has been followed in designing each of them.

On page 70, Prof. Marks' treatise on "The Steam Engine," the work of friction per square inch of projected area is given as 49,908 inch-pounds, while in the cases illustrated in table appended, the work is $12 \times 3{,}309{\cdot}9 = 39{,}718{\cdot}8$ inch-pounds, or a margin of area over 10 per cent. If, however, the averages of the best ten performances shown in the table are taken, we have work of friction per square inch projected area equal to $12 \times 5{,}086{\cdot}6 = 61{,}039{\cdot}2$, or the margin is exceeded by over 10 per cent.

The practice recommended in designing crank-pins is to deduce the length as shown in § 30 of Prof. Marks' treatise on "Steam Engine," and then the diameter as illustrated in §§ 32, 33. A check to the result thus obtained is illustrated in the following formula, in which c = coefficient of friction of rubbing surfaces; v = velocity of rub-

NAME OF VESSEL.	Diameter of cylinder in inches.	Pressure per square inch on piston, in pounds.	Total pressure on piston, in pounds.	No. of strokes of piston per minute.	Length of crank-pin in inches.	Diameter of crank-pin in inches.	Square inches of projected area of crank-pin.	Velocity of rubbing surface of crank-pin, in feet, per minute.	Total work of friction of crank-pin in foot-pounds per minute, the co-efficien of friction being 0·05.	Work of friction on a square inch of projected area of crank-pin, in foot-pounds per minute.	Pressure per square inch of projected area of crank-pin, in pounds.	Work of friction on crank-pin, transmuted into heat units per hour.	Heat units per hour, per square inch of projected area of crank-pin.	REMARKS.
U. S. S. Despatch	33⅛	21·8	18787·24	129	8	9	72	151·97	142,748	1982·6	260·93	11094·4	154·0	JOURNAL OF THE FRANKLIN INSTITUTE, 1882.
" "	33¼	21·8	19084·34	129	8	9	72	151·97	145,010	2014·0	265·06	11270·2	156·5	
" Essex	34	28·0	25421·20	152	16	10	160	198·968	252,900	1580·6	155·88	19643·5	122·7	Edwards' "American Marine Engines."
" "	51	12·0	24513·60	152	16	10	160	198·968	243,870	1524·2	153·21	18553·6	118·4	
" Galena	42	28·8	39890·10	130	18½	10½	194·25	178·678	356,370	1994·2	205·35	27607·1	142·0	1,100 designed HP. equally divided between the two cylinders.
" "	64	12·3	39890·10	130	18½	10½	194·25	178·678	356,370	1994·2	205·35	27607·1	142·0	
" Miantonomah	32	36·0	28952·40	130	15	9⅝	144·375	163·78	223,810	1619·5	200·54	18171·7	125·9	Designed HP. of engines equally divided between the cylinders.
" "	48	16·0	28952·40	130	15	9⅝	144·375	163·78	223,810	1619·5	200·54	18171·7	125·9	
" Quinnebaug	42	32·9	45579·66	122	17½	10½	183·75	167·68	384,425	2092·1	248·05	29877·6	162·6	Trial trip up Chesapeake Bay, December 6, 1878.
" "	64	12·4	39890·80	122	17½	10½	183·75	167·68	336,360	1830·5	217·09	26129·0	141·1	
H. M. S. Alexandra	70	23·0	88515·50	134	17½	17½	306·25	306·96	1,358,500	4436·2	289·03	105590·0	312·1	King's "War Ships of the World."
" "	90	14·0	89063·80	134	17½	17½	306·25	306·96	1,366,900	4463·3	290·82	106235·7	314·2	King's "War Ships of the World."
" "	90	14·0	89063·80	134	17½	17½	306·25	306·96	1,366,900	4463·3	290·82	106235·7	314·2	King's "War Ships of the World."
" Garnet	57	26·0	66346·80	180	13	13	169	306·27	1,016,120	6012·5	392·58	78773·0	455·5	King's "War Ships of the World."
" "	90	10·2	16797·85	180	13	13	169	306·27	1,023,000	6053·2	395·25	79507·7	470·4	King's "War Ships of the World."
" Rover	72	37·0	150645·50	136	14	20	288	356·048	2,681,950	9578·4	538·02	207146·4	739·8	"Engineering," 1876.
" "	88	12·0	72985·20	136	14	20	288	356·048	1,299,300	4640·3	260·66	100968·9	360·6	" "
" "	88	10·5	63862·050	136	14	20	288	356·048	1,136,900	4060·3	224·50	88347·1	315·5	" "
" Téméraire	70	29·0	111606·50	147·2	17½	17½	306·25	336·198	1,876,170	6126·2	364·43	145816·3	476·1	King's "War Ships of the World."
" "	114	11·0	112277·66	147·2	17½	17½	306·25	336·198	1,887,500	6163·2	366·62	146696·9	478·9	King's "War Ships of the World."
U. S. F. C. S. Fish Hawk	22	30·49	11589·25	206	6½	4¾	30·875	128·085	74,215	2403·7	375·36	5768·0	186·8	H. P. cylinder of engine.
S. S. City of San Francisco	51	27·3	55768·44	92	18	16	288	192·685	537,290	1865·6	193·64	41758·3	145·0	Edwards' "American Marine Engines."
" "	88	8·36	50845·356	92	18	16	288	192·685	489,870	1700·9	176·61	38072·8	132·2	Edwards' "American Marine Engines."
" City of Tokio	51	27·3	45768·44	102	17	16	272	213·628	695,675	2557·6	205·03	54068·0	198·1	Edwards' "American Marine Engines."
" "	88	10·8	65670·68	102	17	16	272	213·628	701,465	2578·9	241·43	54518·0	200·4	Edwards' "American Marine Engines."
" Leerdam	39½	36·8	44094·72	124	12½	12	150	194·779	420,420	2802·8	293·96	33374·7	222·5	"Engineer," 1882."
" "	69	10·54	39412·22	124	12½	12	150	194·779	383,830	2558·9	262·81	29831·3	198·9	" "
Yacht Leila	16	20·409	4102·209	443	3½	3⅞	13·5625	224·705	40,090	3398·9	302·52	3582·1	264·1	Report to Bureau of Steam Engineering, U. S. Navy Department.
" "	9	53·756	3419·419	443	4½	2¼	10·125	180·475	22,308	2203·2	337·72	1733·8	171·2	
S. S. Ohio	67¼	33·0	84948·60	120	20	16	320	251·328	1,067,480	3335·9	265·46	82064·7	259·2	"Engineering," 1876, and King's "War Ships of the World."
" "	90½	7·6	48483·44	120	20	16	320	251·328	600,255	1903·9	151·51	47351·4	148·0	
Averages of 31 pins										3300·9	269·15		250·1	
Best 10 results										5086·6	365·41		387·1	

bing surfaces in feet per minute; p = effective pressure on each square inch of piston area; A = square inches of area of piston; l = length of pin, and d = diameter of pin, each in inches; then the heat units are

$$(1)\quad \frac{60p.Avc}{772} = 250ld \text{ or } ld = 0{\cdot}000015545p.Av, \text{ when } c = 0{\cdot}05.$$

To illustrate the problem of the crank-pin dimensions, take the case of the *Galena*, whose crank-pin is 18½ inches long and 10½ inches in diameter.

By formula (81) § 30 of "Steam Engine," by Prof. Marks, length of pin = 0·0000247 × 0·05 × 130 × 64 × 64 = 8·088 inches.

By formula (85) § 34,

$$\text{diameter of pin} = \frac{0{\cdot}00157 \times 64 \times 64 \times 12{\cdot}3}{8{\cdot}088} = 10\tfrac{1}{4} \text{ inches.}$$

By formula (1) above,

$$\text{length of pin} = \frac{0{\cdot}000015545 \times 39890 \times 178{\cdot}7}{10{\cdot}5} = 10{\cdot}55$$

If in formula (1) 387 is used in the place of 250 (see table), the

$$\text{length of pin} = \frac{60 \times 39890 \times 178{\cdot}7 \times 0{\cdot}05}{772 \times 387 \times 10{\cdot}5} = 7 \text{ inches (nearly).}$$

In § 44 of "Friction and Lubrication," by Prof. Thurston, the temperature of vaporization of lubricating oils is given as 600°F., and on page 78 is the following table:

Oil.	Flash.	Takes fire.	Burns.
Winter sperm,	425°F.	485°F.	500°F.
Lard,	475°	525°	525°

All of which shows that the temperatures of vaporization of oils, and not the point of fusibility of the metals, are to be considered in designing crank-pins. Now if the rates of transmission of heat through various metals, as determined by Chief Engineer Isherwood (see page 57 of Shock's "Steam Boilers"), are taken as practically correct for crank-pins, in the most aggravated case, the high-pressure cylinder of the *Rover*, the temperature of the pin, if properly lubricated, should not be increased over 2° in temperature. But as no experiments have ever been made to determine the temperature of the crank-pin brasses, we are forced to adopt existing methods of design.

U. S. S. *Galena*, Montevideo, Uraguay, December 6, 1882.

ON THE APPLICATION OF THE PRINCIPLE OF VIRTUAL VELOCITIES TO THE DETERMINATION OF THE DEFLECTION AND STRESSES OF FRAMES.

By GEORGE F. SWAIN, S.B.
Instructor of Civil Engineering in the Massachusetts Institute of Technology, Boston, Mass.

(Continued from page 115.)

IV. THE ARCH HINGED AT CROWN (Fig. 8).

This case, though of no practical importance, is here introduced simply for the sake of completeness. Two conditions must be sought from the theory of elasticity in order to find the reactions. The third is that the moment at the hinge is zero, or that the resultant R, of the loads and reactions on either side of the hinge, must pass through the

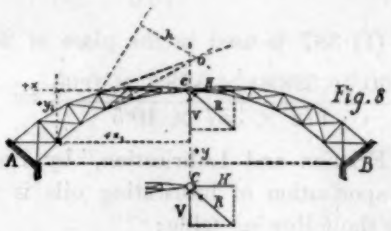


Fig. 8

hinge. Let us resolve R, the resultant on the right, into its horizontal and vertical components, V and H. It is clear that if we find the values of V and H we have solved the problem, because then R is known, and we can compound it with the loads on either side of the hinge, and so find either reaction. Let V and H be called positive when they act in the directions given in the figure, that is, when the vertical component of the resultant of the forces on the right of the hinge acts upward, and the horizontal component of this resultant acts toward the left. For greater clearness, let us denote by subscript r and l when the forces R, V, and H, refer to the right-hand or left-hand halves of the arch. Now, if we replace the right-hand half by R_r, the forces applied to the left-hand half (including R_r) will cause a certain horizontal and vertical deflection of the point C, each of which we can easily calculate, in terms of V and H, which are unknown.

Similarly, for the right-hand half of the arch we can calculate the deflection of C in each direction. The two conditions necessary to solve the problem are clearly these: that the horizontal deflection of C for each half shall be equal in amount, and that the same shall be true for the vertical deflection of C. We have, then, to find values for these deflections, and to place them equal to each other. We proceed as follows: call v_1 the stress produced in any bar of the left-hand bar by a force equal to unity, acting *downward* at C; h_1 that produced by a unit force acting in the same point horizontally *toward the right.* Let the stress produced in the same bar by the applied loads—considered as the only forces acting on the left-hand half, the right-hand half being removed—be s_1; that produced by H, x_1; and that produced by V, y_1. Then we have

$$x_1 = -Hh_1 : Y_1 = -Vv_1.$$

The real stress in the bar is $s_1 + x_1 + y_1 = S$.

The vertical downward deflection of C, the left-hand half only being considered, is

$$\Delta_v = \Sigma_1 v_1 \frac{s_1 \cdot l}{FE} + \Sigma_1 v_1 \frac{x_1 \cdot l}{FE} + \Sigma_1 v_1 \frac{y_1 \cdot l}{FE}$$

$$= \Sigma_1 \frac{v_1 s_1 \cdot l}{FE} - H\Sigma_1 \frac{v_1 h_1 l}{FE} - V\Sigma_1 \frac{v_1^2 l}{FE}, \qquad (14)$$

the summations being extended over the left-hand half.

Similarly, the horizontal deflection of C to the right, considering only the left-hand half, is

$$\Delta_h = \Sigma_1 h_1 \cdot \frac{s_1 l}{FE} + \Sigma_1 h_1 \cdot \frac{x_1 l}{FE} + \Sigma_1 h_1 \cdot \frac{y_1 l}{FE}$$

$$= \Sigma_1 \frac{h_1 s_1 l}{FE} - H\Sigma_1 \frac{h_1^2 l}{FE} - V\Sigma_1 \frac{h_1 v_1 l}{FE}. \qquad (15)$$

By considering the right-hand half alone, we get the following two equations: for the vertical downward deflection,

$$\Delta'_v = \Sigma_r \frac{v_r s_r l}{FE} + H\Sigma_r \frac{v_r h_r l}{FE} + V\Sigma_r \frac{v_r^2 l}{FE}; \qquad (16)$$

and for the horizontal deflection towards the right,

$$\Delta'_h = \Sigma_r \frac{h_r s_r l}{FE} + H\Sigma_r \frac{h_r^2 \cdot l}{FE} + V\Sigma_r \frac{h_r v_r l}{FE}. \qquad (17)$$

The two conditions given by the theory of elasticity are, therefore: $\Delta_v = \Delta'_v$, and $\Delta_h = \Delta'_h$, or

$$\Sigma_1 \frac{v_1 s_1 l}{FE} - H \Sigma_1 \frac{v_1 h_1 l}{FE} - V \Sigma_1 \frac{v_1^2 l}{FE}$$

$$= \Sigma_r \frac{v_r s_r l}{FE} + H \Sigma_r \frac{v_r h_r l}{FE} + V \Sigma_r \frac{v_r^2 l}{FE}. \qquad (18)$$

$$\Sigma_1 \frac{h_1 s_1 l}{FE} - H \Sigma_1 \frac{h_1^2 l}{FE} - V \Sigma_1 \frac{h_1 v_1 l}{FE}$$

$$= \Sigma_r \frac{h_r s_r l}{FE} + H \Sigma_r \frac{h_r^2 l}{FE} + V \Sigma_r \frac{h_r v_r l}{FE}. \qquad (19)$$

These equations become simple when numerical values are inserted, and from them V and H can be found, being the only unknown quantities. The remainder of the discussion regarding this form of arch does not belong here.

We may note briefly, however, a transformation similar to that given for the previous case. Equation (18) may be written

$$\Sigma_1 \frac{v_1 S l}{FE} = \Sigma_r \frac{h_r S l}{FE}, \qquad (20)$$

and equation (19)

$$\Sigma_1 \frac{h_1 S l}{FE} = \Sigma_r \frac{h_r S l}{FE}. \qquad (21)$$

Considering always a moment M as positive when the resultant force on the left of a given section has a right-handed moment with reference to the origin of moments, we may write

$$S = \frac{M}{h}\ ;\ v_1 = -\frac{x_1}{h}\ ;\ h_1 = -\frac{y_1}{h}\ ;\ v_r = \frac{+x_r}{h}\quad h_r\ ; = \frac{+y_r}{h}\ ;$$

h being always put in with its proper sign, so that when M and h are both positive, the stress is a tension.

In these equations C is taken as the origin of co-ordinates, with x positive to the left and y positive downwards, the co-ordinates x_1, y_1, x_r, y_r, being those of the origin of moments for the bar in question. Substituting these values in (20) and (21), we have,

$$\Sigma_1 \frac{M x_1 l}{EF h^2} = -\Sigma_r \frac{M x_r l}{EF h^2}. \qquad (22)$$

$$\Sigma_1 \frac{M y_1 l}{EF h^2} = -\Sigma_r \frac{M y_r l}{EF h^2}. \qquad (23)$$

Neglecting the web members, these equations reduce approximately to the following, as a little consideration will show:

$$\Sigma \frac{Mxl}{I} = o. \tag{24}$$

$$\Sigma \frac{Myl}{I} = o. \tag{25}$$

equations analogous to those given for solid ribs, viz:

$$\int \frac{Mxds}{I} = o\,; \int \frac{Myds}{I} = o.$$

The signs of the various quantities considered must be carefully borne in mind in forming their sums. For the purposes of this article this need not be enlarged upon.

V. The Arch Without Hinges.

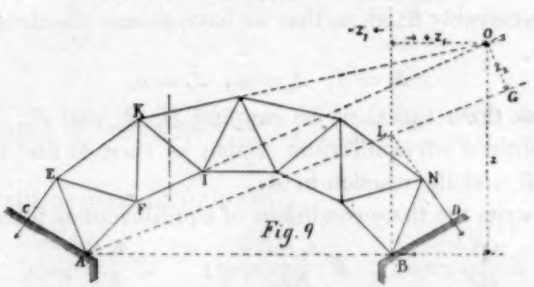


Fig. 9

We approach now the last case of frames supported at two points, and the most difficult case of all. Three conditions have to be supplied by the theory of elasticity. Those given for solid arches are, that the vertical and horizontal deflections of one end, with reference to the other, are zero, and that the ends remain fixed in direction,—conditions reducing to three independent equations. In the case of frames, various methods of treatment are possible. The following is due to Winkler.

Supposing three bars to start from each abutment, we can replace the unknown reactions by the stresses in these bars, so that we have six unknown quantities. Suppose, also, that the bars at the abutments are as in the figure. We take the point A as immovable, B as sliding (for the present) on a horizontal surface, so that we consider the frame as supported at two points, by vertical reactions. We can calculate now, under this supposition, the stress S_v, in any bar IK, due to the given vertical loads, and also the stresses s, s_1, and s_2, in IK, due to a load unity

acting outward respectively in B (along AB), in C (along EC), and in D (along ND). Call the *real* forces acting in these points, H (acting inward, along BA), R_1 (acting inward, along CE), and R_2 (acting inward, along DN). Then the real stress in IK is $S_v - sH - s_1 R_1 - s_2 R_2$. The horizontal deflection of B, outward, is

$$\Delta_b = \Sigma \frac{s S_v l}{EF} - H\Sigma \frac{s^2 l}{EF} - R_1 \Sigma \frac{s s_1 l}{EF} - R_2 \Sigma \frac{s s_2 l}{EF}. \qquad (26)$$

The outward deflection of C is also clearly,

$$\Delta_c = \Sigma \frac{s_1 S_v l}{EF} - H\Sigma \frac{s_1 s l}{EF} - R_1 \Sigma \frac{s_1^2 l}{EF} - R_2 \Sigma \frac{s_1 s_2 l}{EF}, \qquad (27)$$

and that of D is

$$\Delta_d = \Sigma \frac{s_2 S_v l}{EF} - H\Sigma \frac{s_2 s l}{EF} - R_1 \Sigma \frac{s_2 s_1 l}{EF} - R_2 \Sigma \frac{s_2^2 l}{EF}. \qquad (28)$$

Each of these quantities, however, must be zero, if the points A, B, C, D, are immovably fixed, so that we have at once the three equations of condition.

$$\Delta_b = o; \quad \Delta_c = o; \quad \Delta_d = o.$$

From these three equations we can find H, R_1, and R_2. The three statical conditions of equilibrium enable us then to find the vertical reaction in B, and the reaction in A.

We may write the three conditions of equilibrium as follows:

$$\Sigma \frac{s.S.l}{EF} = o; \qquad \Sigma \frac{s_1.S.l}{EE} = o; \qquad \Sigma \frac{s_2.S.l}{EF} = o,$$

or $\qquad \Sigma s.\, \Delta l = o; \qquad \Sigma s_1.\, \Delta l = o; \qquad \Sigma s_2.\, \Delta l = o.$

S being the real stress in any bar, and Δl its elongation. As before, we have $S = \frac{M}{h}$. If we draw BL vertical, and call L its intersection with the bar DN, we can also put $s = \frac{+z}{h}$, where $z =$ distance of O above AB, the point O being the origin of moments for any bar. Further, a unit force outward, in C causes a downward reaction in B, which we call d; if z_1 denotes the distance of O to the right of BL, we have the moment about O of the forces to the right of the section equal to $+dz_1$, and negative; hence $s_1 = \frac{+dz_1}{h}$. An outward force equal to unity in D causes a vertical reaction in B, and an outward reaction in A along LA, which we call d^1. If, therefore, O be above AL, and $OG = z_2$, we have $s_2 = \frac{+d^1 z_2}{h}$. These stresses, it will be

remembered, are those in the bar *IK*, due to unit load in *B*, *C*, and *D*. *d* and d^1 are constants.

Substituting these values, we have

$$\Sigma \frac{z\,Ml}{Fh^2} = o;\ \Sigma \frac{z_1 Ml}{Fh^2} = o;\quad \Sigma \frac{z_2 Ml}{Fh^2} = o.$$

If we take two rectangular axes, *X* and *Y*, in the plane of the frame, we can express z, z_1 and z_2, as follows, in terms of x and y, the co-ordinates of the point *O*.

$$z = a + b\,x + c\,y;\ z_1 = a_1 + b_1 x + c_1 y;\ z_2 = a_2 + b_2 x + c_2 y.$$

Substitute these values, and we have

$$a\,\Sigma \frac{Ml}{Fh^2} + b\,\Sigma \frac{x\,Ml}{Fh^2} + c\,\Sigma \frac{y\,Ml}{Fh^2} = o. \tag{29}$$

$$a_1 \Sigma \frac{Ml}{Fh^2} + b_1 \Sigma \frac{x\,Ml}{Fh^2} + c_1 \Sigma \frac{y\,Ml}{Fh^2} = o. \tag{30}$$

$$a_2 \Sigma \frac{Ml}{Fh^2} + b_2 \Sigma \frac{x\,Ml}{Fh^2} + c_2 \Sigma \frac{y\,Ml}{Fh^2} = o. \tag{31}$$

These equations give the following,

$$\Sigma \frac{Ml}{Fh^2} = o;\ \Sigma \frac{x\,Ml}{Fh^2} = o;\ \Sigma \frac{y\,Ml}{Fh^2} = o; \tag{32}$$

and these equations bear some analogy to those sometimes given for solid arches, namely,

$$\int \frac{M\,ds}{I} = o;\ \int \frac{M\,x\,ds}{I} = o;\ \int \frac{M\,y\,ds}{I} = o,$$

provided we neglect the influence of the web members.

The further discussion of the best methods of applying these equations would occupy too much space, and we must refer to Winkler's original article.*

We have now seen how the method which we have explained is applied to arches. It remains, before taking leave of cases where the outer forces are statically undetermined, to discuss the one remaining case of importance, viz., the continuous girder.

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* Winkler. Beitrag zur Theorie der Bogenträger Zeitschr. d. Archit. & Ing. Vereins zu Hannover. 1879. Page 199.

VI. The Continuous Girder (Fig. 10).

Consider a continuous girder of n spans, their lengths being l_1, l_2, l_3, —— l_n. Let the reactions be R_1, R_2, R_3, —— R_{n+1}; and let the total length, $l_1 + l_2 + l_3 + \text{——} l_n, = L$. Supposing the reactions to be

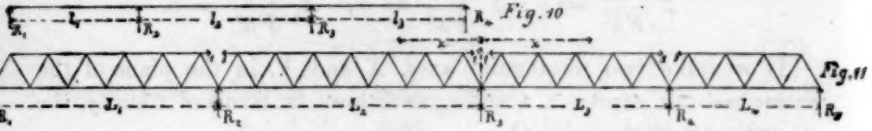


Fig. 10

Fig. 11

all vertical but one, and applied at given points, and the loads vertical or inclined, we have $n + 2$ unknown quantities, one at each point of support where the reaction is vertical, and two at the remaining point of support. Statics affords only three equations, so that there are $n - 1$ equations to be obtained from the theory of elasticity. These are given by the conditions of the supports, and taking the line joining the end supports as an axis, we have to express that at each intermediate support the deflection is zero or a given quantity. We then obtain $n - 1$ equations, and can solve the problem. The resulting equations are the following: Let h_2, h_3, etc., be the deflections of the intermediate supports *below* the line joining the end supports. Let S be the actual stress in any bar, l its length, E its modulus of elasticity, and F its cross section; let t_2 be the stress caused in it by a load unity acting *downward* at the second point of support, t_3 that caused by an equal load at the third, t_4 that at the fourth—all calculated as though the girder were simple, and had a length, L. Let the stress caused in the bar by the given load acting on the girder, calculated as a beam of length, L, be s. Then the real stress S, in any bar, is

$$S = s - t_2 R_2 - t_3 R_3 - t_4 R_4 \cdots\cdots - t_n R_n \qquad (33)$$

and the conditions which we have are

$$\left.\begin{aligned} h_2 &= \Sigma_0^L t_2 \frac{Sl}{EF} \\ h_3 &= \Sigma_0^L t_3 \frac{Sl}{EF} \\ h_4 &= \Sigma_0^L t_4 \frac{Sl}{EF} \\ &\cdots\cdots\cdots\cdots \\ h_n &= \Sigma_0^L t_n \frac{Sl}{EF} \end{aligned}\right\} \qquad (34)$$

These equations may also be written as follows:

$$\left.\begin{aligned}
h_2 &= \overset{L}{\Sigma_\circ}\, t_2 \frac{s\,l}{EF} - R_2 \overset{L}{\Sigma_\circ} \frac{t_2^2\, l}{EF} - R_3 \overset{L}{\Sigma_\circ}\, t_2 \frac{t_3\, l}{EF} - \\
&\quad R_4 \overset{L}{\Sigma_\circ}\, t_2 \frac{t_4\, l}{EF} \cdots\cdots - R_n \overset{L}{\Sigma_\circ}\, t_2 \frac{t_n\, l}{EF} \\
h_3 &= \overset{L}{\Sigma_\circ}\, t_3 \frac{s\,l}{EF} - R_2 \overset{L}{\Sigma_\circ}\, t_3 \frac{t_2\, l}{EF} - R_3 \overset{L}{\Sigma_\circ}\, t_3^2 \frac{l}{EF} \\
&\quad - R_4 \overset{L}{\Sigma_\circ}\, t_3 \frac{t_4\, l}{EF} \cdots\cdots - R_n \overset{L}{\Sigma_\circ}\, t_3 \frac{t_n\, l}{EF} \\
h_4 &= \overset{L}{\Sigma_\circ}\, t_4 \frac{s\,l}{EF} - R_2 \overset{L}{\Sigma_\circ}\, t_4 \frac{t_2\, l}{EF} - R_3 \overset{L}{\Sigma_\circ}\, t_4 \frac{t_3\, l}{EF} - \\
&\quad R_4 \overset{L}{\Sigma_\circ}\, t_4^2 \frac{l}{EF} \cdots\cdots - R_n \overset{L}{\Sigma_\circ}\, t_4 \frac{t_n\, l}{EF} \\
h_n &= \overset{L}{\Sigma_\circ}\, t_n \frac{s\,l}{EF} - R_2 \overset{L}{\Sigma_\circ}\, t_n \frac{t_2\, l}{EF} - R_3 \overset{L}{\Sigma_\circ}\, t_n \frac{t_3\, l}{EF} \\
&\quad - R_4 \overset{L}{\Sigma_\circ}\, t_n \frac{t_4\, l}{EF} \cdots\cdots - R_n \overset{L}{\Sigma_\circ}\, \frac{t_n^2\, l}{EF}
\end{aligned}\right\} \quad (35)$$

These equations are $n - 1$ in number, and the only unknown quantities are the $n - 1$ reactions, R_2 ..... R_n, These once obtained, the problem is solved. We shall refer again to another solution of the continuous girder, by which equations are obtained which may be easily reduced to those obtained by the theorem of three moments.

VII. Trusses with Superfluous Bars.

We consider here the case of plane systems which are statically undetermined regarding the inner forces, and in which the number of equations is less than the number of unknown quantities, or in which $2m - 3 < n$. To solve such a system, the following is our method of procedure:

Suppose at any two joints A and B of the frame, forces equal to unity to act, along AB, and towards each other. These forces will, in general, cause reactions at the point of support, and stresses in the bars. Let the stress caused in any bar CD be called u, and let Δl be the change in length of the bar CD and Δp that of the line AB. Then, according to the principle of virtual velocities, supposing all the bars to be unelastic except CD.

$$1.\ \Delta p = u\ \Delta l \quad (36)$$

Δp and Δl being the absolute changes of length, without reference to sign. If, now, all the bars are elastic

$$\Delta p = \Sigma\, u\, \Delta l \tag{37}$$

In a system such as we are considering, if we omit $n - 2m + 3$ bars, we can make the system statically determined, by properly choosing the bars to be omitted, which may be called *superfluous*, while those remaining may be called *necessary*. Now, in place of one of the superfluous bars AB, let us apply at the joints where it is connected, acting towards each other (and hence representing tension in the bar) forces equal to unity. Let us use the following notation:

λ_1, λ_2, λ_3, etc. = length of the superfluous bars.

l_1, l_2, l_3, etc. = length of the necessary bars.

u_1', u_2', u_3', etc. = stresses caused in the bars of the now statically determined system by the unit forces along AB, as above described.

Δl_1, Δl_2, Δl_3, etc. = changes of length of the necessary bars, under these conditions.

Then we have, for the shortening of AB,

$$\Delta\lambda_1 = \Sigma u'\, \Delta l \tag{38}$$

Further, let

Y_1, Y_2, Y_3, etc. = stresses produced in the now statically determined system (in the necessary bars) by the given outer forces acting on the frame. These may be found by the principles of statics alone.

S_1, S_2, S_3, etc. = real stresses in the necessary bars as parts of the statically undetermined system, *i.e.*, when the superfluous bars are present.

S', S'', S''', etc. = the real stresses in the superfluous bars.

u_1'', u_2'', u_3'', etc. = stresses produced in the bars of the statically determined system (the superfluous bars being removed) by the force unity at each end of some other of the superfluous bars, $A'\,B'$, acting towards each other (tension).

u_1''', u_2''', u_3''', etc. = similar stresses produced by unit forces along another superfluous bar $A''\,B''$, etc.

Then we have clearly,

$$\left.\begin{aligned} S_1 &= Y_1 + u_1'\,S' + u_1''\,S'' + u_1'''\,S''' + \quad - \quad \text{——} \\ S_2 &= Y_2 + u_2'\,S' + u_2''\,S'' + u_2'''\,S''' + \quad - \quad \text{——} \\ S_3 &= Y_3 + u_3'\,S' + u_3''\,S'' + u_3'''\,S''' + \quad - \quad \text{——} \end{aligned}\right\} \tag{39}$$

etc., etc.

In these equations Y_1, Y_2, Y_3, u_1', u_2', u_3', etc., may be determined by the elementary principles of statics, while S_1, S_2, S_3, S', S'', S''', etc., are yet unknown.

Let us now denote as follows:

f_1, f_2, f_3, etc. = sections of the necessary bars.

f', f'', f''', etc. = sections of the superfluous bars.

E_1, E_2, E_3, etc. = moduli of elasticity of the necessary bars.

E', E'', E''', etc.= moduli of elasticity of the superfluous bars.

Δl_1. Δl_2, Δl_3, etc. = real changes of length of the necessary bars.

$\Delta\lambda_1$, $\Delta\lambda_2$, $\Delta\lambda_3$, etc. = real changes of length of the superfluous bars.

Then we have

$$\left.\begin{aligned} \Delta l_1 &= \frac{l_1 S_1}{E_1 f_1} = K_1 S_1, \text{ if } \frac{l_1}{E_1 f_1} = K_1 \\ \Delta l_2 &= \frac{l_2 S_2}{E_2 f_2} = K_2 S_2, \text{ if } \frac{l_2}{E_2 f_2} = K_2 \end{aligned}\right\} \quad (40)$$

Similarly,

$$\Delta l_3 = K_3 S_3; \ \Delta l_4 = K_4 S_4, \text{ etc.}$$

$$\Delta\lambda_1 = K' S'; \ \Delta\lambda_2 = K'' S''; \ \Delta\lambda_3 = K''' S''', \text{ etc.}$$

If we always call tension positive aud compression negative, the change of length will be positive when the length is increased, and negative when it is diminished. If we find the value of $u' \Delta l_1$ in equation (38), it will be always positive, for u' and Δl_1 will be both positive or both negative. In that equation, however, Δl_1 was the change of length produced in one of the necessary bars by a unit tension in one of the superfluous bars, AB. Expressed in words, that equation states that if we multiply the change of length, Δl, of each necessary bar, by the stress produced in it by unit forces along AB, acting towards each other, the sum of the values so found will be the *shortening* of AB; and this will be the case if we only insert for Δl the real change of length, from whatever cause. If the points A and B, however, are connected by the superfluous bar AB, the shortening of AB is $-K' S'$, tension being positive. Substitute now in equation (38) the values of $\Delta\lambda_1$ and Δl, and we have the first of the following equations.

$$\left.\begin{aligned} -K'\,S' &= u_1'\,K_1\,S_1 + u_2'\,K_2\,S_2 + u_3'\,K_3\,S_3 + \ldots\ldots \\ -K''\,S'' &= u_1''\,K_1\,S_1 + u_2''\,K_2\,S_2 + u_3''\,K_3\,S_3 + \ldots\ldots \\ -K'''\,S''' &= u_1'''\,K_1\,S_1 + u_2'''\,K_2\,S_2 + u_3'''\,K_3\,S_3 + \ldots\ldots \end{aligned}\right\} \quad (41)$$

Finally, substituting for S_1, S_2, S_3, etc., their values from (39) we have

$$\left.\begin{aligned} K'\,S' &= -u_1'\,K_1\left(Y_1 + u_1'\,S' + u_1''\,S'' + u_1'''\,S''' + \ldots\ldots\right) \\ &\quad - u_2'\,K_2\left(Y_2 + u_2'\,S' + u_2''\,S' + u_2'''\,S''' + \ldots\ldots\right) \\ K''\,S'' &= -u_1''\,K_1\left(Y_1 + u_1'\,S' + u_1''\,S'' + u_1'''\,S''' + \ldots\ldots\right) \\ &\quad - u_2''\,K_2\left(Y_2 + u_2'\,S' + u_2''\,S'' + u_2'''\,S''' + \ldots\ldots\right) \end{aligned}\right\} \quad (42)$$

These may be transformed to the following:

$$\left.\begin{aligned} &S'\,(K' + u_1'\,u_1'\,K_1 + u_2'\,u_2'\,K_2 + \ldots\ldots) + S''\,(u_1'\,u_1''\,K_1 \\ &+ u_2'\,u_2''\,K_2 + \ldots\ldots) + S'''\,(u_1'\,u_1'''\,K_1 + u_2'\,u_2'''\,K_2 + \\ &\ldots\ldots) + u_1'\,K_1\,Y_1 + u_2'\,K_2\,Y_2 + \ldots\ldots = o \\ &S'\,(u_1'\,u_1''\,K_1 + u_2'\,u_2''\,K_2 + \ldots\ldots) + S''\,(K'' + u_1''\,u_1'' \\ &K_2 + u_2''\,u_2''\,K_2 + \ldots\ldots) + S'''(u_1''\,u_1'''K_1 + u_2''\,u_2'''K_2 + \\ &\ldots\ldots) + u_1''\,K_1\,Y_1 + u_2''\,K_2\,Y_2 + \ldots\ldots = o. \end{aligned}\right\} \quad (43)$$

These equations are equal in number to the superfluous bars. From them, therefore, the unknown stresses S', S'', S''' etc. may be determined, after which the stresses S_1, S_2, S_3, etc., may be found from equations (39).

This method, which appears complex when treated in its general form, becomes simple when applied to any particular case, if the calculation is made methodically, and the results arranged in tabular form. It is scarcely necessary to exemplify its application. Statically undetermined systems should be avoided by the constructor when practicable, except in some cases where they afford practical advantages sufficient to more than balance the uncertainty in the calculation by ordinary methods.

(To be continued.)

DESCRIPTION OF AN ELECTRIC SIGNAL CLOCK.

By Aaron D. and Geo. W. Blodgett.

[A paper read at the stated meeting of the Franklin Institute, December 20, 1882.]

The requirements of business at the terminus of a railway of any considerable magnitude necessitates the arrival and departure of a large number of trains.

The development of the country through which it passes, and the increased traffic which is the consequence thereof, call for constant addition to its facilities for the safe and convenient transportation of passengers.

The problem of dispatching fifty, sixty, or a hundred trains per day with promptness and regularity has become so important that only the most reliable men are considered competent for this work. But with the utmost care, mistakes are made and delays occur which are detrimental to the business of the road, and endanger the lives of its patrons.

The usual method of giving signals for the departure of railway trains is to put the signal bells in charge of the ticket agent, who, besides answering questions, selling tickets, and making change, gives signals for the trains to depart, as well as the usual preliminary signals.

It is not at all surprising that, as is always found to be the case, much irregularity exists in the time of the signals; that at the critical moment something else often engages the operator's attention, and the signal is delayed and sometimes forgotten; or in the effort to start trains promptly, it is given too early and the train departs before it should.

Careful observation shows that errors of this kind will happen with the most painstaking men, and even in cases where the operator's only business is to dispatch trains, the inaccuracy is greater than is commonly supposed.

Experience teaches that whenever machinery can be substituted for human labor, greater accuracy can be attained.

So far as we know, a machine has never yet been invented which would answer questions, sell tickets, or make change; but we are able to show a machine which will give correctly the warning and departure signals for any number of trains in their proper order.

The essential features of this machine are:—

A cylinder which is provided with a separate hole for each minute in the twenty-four hours.

A shoe, or follower, is so contrived as to pass over every hole in the cylinder once a day. This is connected with suitable circuit-closing mechanism in such a way that a slight movement of the shoe away from the cylinder, will set in operation the signaling apparatus.

Small pins are screwed into the holes which correspond in location to the times when signals should be given.

The operation of the machine, which will be readily understood, is as follows:

A standard clock (which is to be found at every railway terminus), is caused to close an electric circuit in a well-known way once each minute.

The current passes through an electro-magnet connected by a pawl to a ratchet-wheel of sixty teeth, which it advances one tooth at each closure of the circuit.

This ratchet rotates the cylinder one step each minute, which, therefore, makes one revolution in an hour.

Most railroads require two signals for the departure of every train, a warning, or preliminary, signal which precedes the other by a certain interval—two, three, or five minutes—and a starting signal sounded at the exact time when the train should depart.

Whenever the follower comes in contact with the pin corresponding to a warning signal, the circuit-closing mechanism is released, and one or more blows are struck upon the bells, according to the signal required. After the lapse of the proper interval, the follower comes in contact with the second pin, and the signal is given for the train to start.

When the time of the next train approaches the operations are repeated, and so on through the time-table.

At twelve o'clock, midnight, the follower having completed its traverse of the holes in the cylinder, is automatically transferred to the first hole of the series and begins a new day.

The cylinder is provided with an additional series of fourteen hundred and forty holes, and with pins corresponding to a Sunday time-table.

A follower also traverses the holes in this part of the cylinder, but cannot set in motion the striking mechanism during a weekday.

At midnight on Saturday the follower which could set in operation on a weekday the mechanism which strikes the bells, is disconnected, and the Sunday time-table rendered operative, striking the signals for trains on that day. At midnight, Sunday, things are restored to the first-described condition for six days more.

The instrument is, therefore, automatic in its operation, requiring only such changes as are necessary in the arrangement of pins, to correspond with changes in the time-table.

The circuit closing mechanism is driven by a spring which requires winding once a week.

A press-button and switch connected with the bells, and under control of the train-dispatcher, enables him to delay a regular signal, or to strike additional ones, should it be desired. Such interruption does not, however, in any way disarrange the apparatus, which, as soon as the switch is closed, resumes its normal operation.

One of these machines has been in use for nearly a year at the depot of the Boston and Albany Railroad, in Boston—the largest in the city—dispatching satisfactorily nearly sixty trains a day. Next in order comes the Boston and Providence Railroad, where over fifty trains a day are sent out in the same manner.

The New York and New England, and the Fitchburg Railroads follow with a less number of trains, which are also dispatched in this way.

The United States Government has recently ordered this machine for the Boston Post Office, where it signals the departure of the mails.

From the foregoing it will be seen that this instrument can be used for many other purposes besides those mentioned, such as the distribution of standard time signals for manufacturing companies, for street railroads, and for use in school-buildings; in short, wherever it is desired to sound signals for any purpose, at regular or irregular intervals.

Any conceivable arrangement of signals is also permissible, the machines in operation at the Boston depots following each a different code.

Only one change is necessary to fulfil all these conditions, and that is simple, and easily made.

The operation of setting up or changing the time-table is so simple that it can be done by any person of average intelligence, with accuracy and in a few moments.

SCIENCE IN RELATION TO THE ARTS.

By C. William Siemens, F. R. S.

(Continued from page 134)

The progressive views perceptible in the construction of the navy are further evidenced in a remarkable degree in the hydrographic department. Captain Sir Frederick Evans, the hydrographer, and Vice-President of the British Association, gave us at York last year a very interesting account of the progress made in that department, which, while dealing chiefly with the preparation of charts showing the depth of water, the direction and force of currents, and the rise of tides near our shores, contains also valuable statistical information regarding the more general questions of the physical conditions of the sea, its temperature at various depths, its flora and fauna, as also the rainfall and the nature and force of prevailing winds. In connection with this subject the American Naval Department has taken an important part, under the guidance of Captain Maury and the Agassiz, father and son, whilst in this country the persistent labors of Dr. William Carpenter deserve the highest consideration.

Our knowledge of tidal action has received a most powerful impulse through the invention of a self-recording gauge and tide-predicter, which will form the subject of one of the discourses to be delivered at our present meeting by its principal originator, Sir William Thomson; when I hope he will furnish us with an explanation of some extraordinary irregularities in tidal records, observed some years ago by Sir John Coode at Portland, and due apparently to atmospheric influence.

The application of iron and steel in naval construction rendered the use of the compass for some time illusory, but in 1839 Sir George Airy showed how the errors of the compass, due to the influence experienced from the iron of the ship, may be perfectly corrected by magnets and soft iron placed in the neighborhood of the binnacle, but the great size of the needles in the ordinary compasses rendered the correction of the quadrantal errors practically unattainable. In 1876 Sir William Thomson invented a compass with much smaller needles than those previously used, which allows Sir George Airy's principles to be applied completely. With this compass, correctors can be arranged so that the needle shall point accurately in all directions, and

these correctors can be adjusted at sea from time to time, so as to eliminate any error which may arise through change in the ship's magnetism or in the magnetism induced by the earth through change of the ship's position. By giving the compass card a long period of free oscillation great steadiness is obtained when the ship is rolling.

Sir William Thomson has also enriched the art of navigation by the invention of two sounding machines; the one being devised for ascertaining great depths very accurately in less than one-quarter the time formerly necessary, and the other for taking depths up to 130 fathoms without stopping the ship in its onward course. In both these instruments steel pianoforte wire is used instead of the hempen and silken lines formerly employed; in the latter machine the record of depth is obtained not by the quantity of wire run over its counter and brake wheel, but through the indications produced upon a simple pressure gauge consisting of an inverted glass tube, whose internal surface is covered beforehand with a preparation of chromate of silver, rendered colorless by the sea-water up to the height to which it penetrates. The value of this instrument for guiding the navigator within what he calls "soundings" can hardly be exaggerated; with the sounding-machine and a good chart he can generally make out his position correctly by a succession of three or four casts in a given direction at given intervals, and thus in foggy weather is made independent of astronomical observations and of the sight of lighthouses or the shore. By the proper use of this apparatus, such accidents as happened to the mail steamer *Mosel* not a fortnight ago would not be possible. As regards the value of the deep-sea instrument I can speak from personal experience, as on one occasion it enabled those in charge of the Cable ss. *Faraday* to find the end of an Atlantic Cable, which had parted in a gale of wind, with no other indication of the locality than a single sounding, giving a depth of 950 fathoms. To recover the cable a number of soundings in the supposed neighborhood of the broken end were taken, the 950 fathom contour line was then traced upon a chart, and the vessel thereupon trailed its grapnel two miles to the eastward of this line, when it soon engaged the cable 20 miles away from the point, where dead reckoning had placed the ruptured end.

Whether or not it will ever be practicable to determine oceanic depths without a sounding line, by means of an instrument based upon gravi-metric differences, remains to be seen. Hitherto the indications obtained by such an instrument have been encouraging, but its delicacy

has been such as to unfit it for ordinary use on board a ship when rolling.

The time allowed me for addressing you on this occasion is wholly insufficient to do justice to the great engineering works of the present day, and I must therefore limit myself to making a short allusion to a few only of the more remarkable enterprises.

The great success, both technically and commercially, of the Suez Canal, has stimulated M. de Lesseps to undertake a similar work of even more gigantic proportions, namely, the piercing of the Isthmus of Panama by a ship canal, 40 miles long, 50 yards wide on the surface, and 20 yards at the bottom, upon a dead level from sea to sea. The estimated cost of this work is 20,000,000*l.*, and more than this sum having been subscribed, it appears unlikely that political or climatic difficulties will stop M. de Lesseps in its speedy accomplishment. Through it, China, Japan, and the whole of the Pacific Ocean will be brought to half their present distance, as measured by the length of voyage, and an impulse to navigation and to progress will thus be given which it will be difficult to over-estimate.

Side by side with this gigantic work, Captain Eads, the successful improver of the Mississippi navigation, intends to erect his ship railway, to take the largest vessels, fully laden and equipped, from sea to sea, over a gigantic railway across the Isthmus of Tehuantepec, a distance of 95 miles. Mr. Barnaby, the chief constructor of the navy, and Mr. John Fowler have expressed a favorable opinion regarding this enterprise, and it is to be hoped that both the canal and the ship railway will be accomplished, as it may be safely anticipated that the traffic will be amply sufficient to support both these undertakings.

Whether or not M. de Lesseps will be successful also in carrying into effect the third great enterprise with which his name has been prominently connected, the flooding of the Tunis-Algerian Chotts, thereby re-establishing the lake Tritonis of the ancients, with its verdure-clad shores, is a question which could only be decided upon the evidence of accurate surveys, but the beneficial influence of a large sheet of water within the African desert could hardly be matter of doubt.

It is with a feeling not unmixed with regret that I have to record the completion of a new Eddystone Lighthouse in substitution for the *chef-d'œuvre* of engineering erected by John Smeaton more than 100 years ago. The condemnation of that structure was not, however, the

consequence of any fault of construction, but was caused by inroads of the sea upon the rock supporting it. The new lighthouse, designed and executed by Mr., now Sir, James Douglass, engineer of Trinity House, has been erected in the incredibly short time of less than two years, and bids fair to be worthy of its famed predecessor. Its height above high water is 130 feet, as compared with 72 feet, the height of Telford's structure, which gives its powerful light a considerably increased range. The system originally suggested by Sir William Thomson some years ago, of distinguishing one light from another by flashes following at varied intervals, has been adopted by the Elder-Brethren in this as in other recent lights, in the modified form introduced by Dr. John Hopkinson, in which the principle is applied to revolving lights, so as to obtain a greater amount of light in the flash.

The geological difficulties which for some time threatened the accomplishment of the St. Gothard Tunnel have been happily overcome, and this second and most important sub-Alpine thoroughfare now connects the Italian railway system with that of Switzerland and the south of Germany, whereby Genoa will be constituted the shipping port for those parts.

Whether we shall be able to connect the English with the French railway system by means of a tunnel below the English channel is a question that appears dependent at this moment rather upon military and political than technical and financial considerations. The occurence of a stratum of impervious grey chalk, at a convenient depth below the bed of the channel, minimizes the engineering difficulties in the way, and must influence the financial question involved. The protest lately raised against its accomplishment can hardly be looked upon as a public verdict, but seems to be the result of a natural desire to pause pending the institution of careful inquiries. These inquiries have been made by a Royal Scientific Commission, and will be referred for further consideration to a mixed Parliamentary Committee, upon whose report it must depend whether the natural spirit of commercial enterprise has to yield in this instance to political and military considerations. Whether the channel tunnel is constructed or not the plan proposed some years ago by Mr. John Fowler of connecting England and France by means of a ferry boat capable of taking railway trains would be a desideratum justified by the ever-increasing inter-communication between this and Continental countries.

The public inconvenience arising through the obstruction to traffic by a sheet of water is well illustrated by the circumstance that both the estuaries of the Severn and of the Mersey are being undermined in order to connect the railway systems on the two sides, and that the Frith of Forth is about to be spanned by a bridge exceeding in grandeur anything as yet attempted by the engineer. The roadway of this bridge will stand 150 feet above high-water mark, and its two principal spans will measure a third of a statute mile each. Messrs. Fowler and Baker, the engineers to whom this great work has been entrusted, could hardly have accomplished their task without having recourse to steel for their material of construction, nor need the steel used be of the extra mild quality particularly applicable for naval structures to withstand collision, for, when such extreme toughness is not required, steel of very homogeneous quality can be produced, bearing a tensile strain double that of iron.

The tensile strength of steel, as is well known, is the result of an admixture of carbon with the iron, varying between $\frac{1}{10}$th and 2 per cent., and the nature of this combination of carbon with iron is a matter of great interest both from a theoretical and practical point of view. It could not be a chemical compound which would necessitate a definite proportion, nor could a mere dissolution of the one in the other exercise such remarkable influence upon the strength and hardness of the resulting metal. A recent investigation by Mr. Abel has thrown considerable light upon this question. A definite carbide of iron is formed, it appears soluble at high temperatures in iron, but separating upon cooling the steel gradually, and influencing only to a moderate degree the physical properties of a metal as a whole. In cooling rapidly there is no time for the carbide to separate from the iron, and the metal is thus rendered both hard and brittle. Cooling the metal gradually under the influence of great compressive force, appears to have a similar effect to rapid cooling in preventing the separation of the carbide from the metal, with this difference, that the effect is more equal throughout the mass, and that more uniform temper is likely to result.

When the British Association met at Southampton on a former occasion, Schönbein announced to the world his discovery of gun-cotton. This discovery has led the way to many valuable researches on explosives generally, in which Mr. Abel has taken a leading part. Recent investigations by him, in connection with Captain Noble, upon

the explosive action of gun-cotton and gunpowder confined in a strong chamber, which have not yet been published, deserve particular attention. They show that while by the method of investigation pursued about twenty years ago by Karolye (of exploding gunpowder in very small charges in shells confined within a large shell partially exhausted of air), the composition of the gaseous products was found to be complicated and liable to variation, the chemical metamorphosis which gun-cotton sustains, when exploded under conditions such as obtained in its practical application, is simple and very uniform. Among other interesting points noticed in this direction was the fact that, as in the case of gunpowder, the proportion of carbonic acid increases, while that of carbonic oxide diminishes with the density of the charge. The explosion of gun-cotton, whether in the form of wool or loosely spun thread, or in the packed compressed form devised by Abel, furnished practically the same results if fired under pressure, that is, under strong confinement—the conditions being favorable to the full development of its explosive force; but some marked differences in the composition of the products of metamorphosis were observed when gun-cotton was fired by detonation. With regard to the tension exerted by the products of explosion, some interesting points were observed, which introduce very considerable difficulties into the investigation of the action of fired gun-cotton. Thus, whereas no marked differences are observed in the tension developed by small charges and by very much larger charges of gunpowder having the same density (*i. e.* occupying the same volume relatively to the entire space in which they are exploded), the reverse is the case with respect to gun-cotton. Under similar conditions in regard to density of charge, 100 grammes of gun-cotton gave a measured tension of about 20 tons on the square inch, 1,500 grammes gave a tension of about 29 tons (in several very concordant observations), while a charge of 2·5 kilos gave a pressure of about 45 tons, this being the maximum measured tension obtained with a charge of gunpowder of five times the density of the above.

The extreme violence of the explosion of gun-cotton as compared with gunpowder when fired in a closed space was a feature attended with formidable difficulties. In whatever way the charge was arranged in the firing cylinder, if it had free access to the enclosed crusher gauge, the pressures recorded by the latter were always much greater than when means were taken to prevent the wave of matter suddenly set in motion from acting directly upon the gauge. The

abnormal, or wave-pressures recorded at the same time that the general tension in the cylinder was measured, amounted in the experiment to 42·3 tons, when the general tension was recorded at 20 tons; and in another when the pressure was measured at 29 tons, the wave-pressure recorded was 44 tons. Measurements of the temperature of explosion of gun-cotton showed it to be about double that of the explosion of gun-powder. One of the effects observed to be produced by this sudden enormous development of heat was the covering of the inner surfaces of the steel explosion-vessel with a net-work of cracks, small portions of the surface being sometimes actually fractured. The explosion of charges of gun-cotton up to 2·5 kilos in perfectly closed chambers, with development of pressures approaching to 50 tons on the square inch, constitutes alone a perfectly novel feat in investigations of this class.

Messrs. Noble and Abel are also continuing their researches upon fired gunpowder, being at present occupied with an inquiry into the influence erected upon the chemical metamorphosis and ballistic effects of fired gunpowder by variation in its composition, their attention being directed especially to the discovery of the cause of the more or less considerale erosion of the interior surface of guns produced by the exploding charge—an effect which, notwithstanding the application of devices in the building up of the charge specially directed to the preservation of the gun's bore, has become so serious that, with the enormous charges now used in our heavy guns, the erosive action on the surface of the bore produced by a single round is distinctly perceptible. As there appeared to be *primâ facie* reasons why the erosive action of powder upon the surface of the bore at the high temperatures developed should be at any rate in part due to its one component sulphur, Noble and Abel have made comparative experiments with powders of usual composition and with others in which the proportion of sulphur was considerably increased, the extent of erosive action of the products escaping from the explosion vessel under high tension being carefully determined. With small charges a particular powder containing no sulphur was found to exert very little erosive action as compared with ordinary cannon powder; but another powder, containing the maximum proportion of sulphur tried (15 per cent.), was found equal to it under these conditions, and exerted very decidedly less erosive action than it, when larger charges were reached. Other important contributions to our knowledge of the action of fired gun-

powder in guns, as well as decided improvements in the gunpowder manufactured for the very heavy ordnance of the present day, may be expected to result from a continuance of these investigations. Professor Carl Himly, of Kiel, having been engaged upon investigations of a similar nature, has lately proposed a gunpowder in which hydrocarbons precipitated from solution in naphtha take the place of the charcoal and sulphur of ordinary powder, this powder has amongst others the peculiar property of completely resisting the action of water, so that the old caution, "Keep your powder dry," may hereafter be unnecessary.

The extraordinary difference of condition, before and after its ignition, of such matter as constitutes an explosive agent leads us up to a consideration of the aggregate state of matter under other circumstances. As early as 1776 Alexander Volta observed that the volume of glass was changed under the influence of electrification, by what he termed electrical pressure. Dr. Kerr, Govi, and others have followed up the same inquiry, which is at present continued chiefly by Dr. George Quincke, of Heidelberg, who finds that temperature, as well as chemical constitution of the dielectric under examination, exercises a determining influence upon the amount and character of the change of volume effected by electrification; that the change of volume may under certain circumstances be effected instantaneously as in flint glass, or only slowly as in crown glass, and that the elastic limit of both is diminished by electrification, whereas in the case of mica and gutta-percha an increase of elasticity takes place.

Still greater strides are being made at the present time towards a clearer perception of the condition of matter when particles are left some liberty to obey individually the forces brought to bear upon them. By the discharge of high tension electricity through tubes containing highly rarefied gases (Geissler's tubes), phenomena of discharge were produced which were at once most striking and suggestive. The Sprengel pump afforded a means of pushing the exhaustion to limits which had formerly been scarcely reached by the imagination. At each step the condition of attenuated matter revealed varying properties when acted upon by electrical discharge and magnetic force. The radiometer of Crookes imported a new feature into these inquiries, which at the present time occupy the attention of leading phycicists in all countries.

The means usually employed to produce electrical discharge in

vacuum tubes was Ruhmkorff's coil; but Mr. Gassiot first succeeded in obtaining the phenomena by means of a galvanic battery of 3,000 Leclanché cells. Dr. De La Rue, in conjunction with his friend Dr. Hugo Müller, has gone far beyond his predecessors in the production of batteries of high potential. At his lecture "On the Phenomena of Electric Discharge," delivered at the Royal Institution in January 1881, he employed a battery of his invention consisting of 14,400 cells (14,832 Volts), which gave a current of 0·054 Ampère, and produced a discharge at a distance of 0·71 inch between the terminals. During last year he increased the number of cells to 15,000 (15,450 Volts), and increased the current to 0·4 Ampère, or eight times that of the battery he used at the Royal Institution.

With the enormous potential and perfectly steady current at his disposal, M. De La Rue has been able to contribute many interesting facts to the science of electricity. He has shown, for example, that the beautiful phenomena of the stratified discharge in exhausted tubes are but a modification and a magnification of those of the electric arc at ordinary atmospheric pressure. Photography was used in his experiments to record the appearance of the discharge, so as to give a degree of precision otherwise unattainable in the comparison of the phenomena. He has shown that between two points the length of the spark, provided the insulation of the battery is efficacious, is as the square of the number of cells employed. Mr. De La Rue's experiments have proved that all pressures the discharge in gases is not a current in the ordinary acceptation of the term, but is of the nature of a disruptive discharge. Even in an apparently perfectly steady discharge in a vacuum tube, when the strata as seen in a rapidly revolving mirror are immovable, he has shown that the discharge is a pulsating one; but, of course, the period must be of a very high order.

At the Royal Institution, on the occasion of his lecture, Mr. De La Rue produced, in a very large vacuum tube, an imitation of the Aurora Borealis; and he has deduced from his experiments that the greatest brilliancy of Aurora displays must be at an altitude of from thirty-seven to thirty-eight miles—a conclusion of the highest interest, and in opposition to the extravagant estimate of 281 miles at which it had been previously put.

The President of the Royal Society has made the phenomena of electrical discharge his study for several years, and resorted in his important experiments to a special source of electric power. In a note

addressed to me, Dr. Spottiswoode describes the nature of his investigations much more clearly than I could venture to give them. He says: "It had long been my opinion that the dissymmetry shown in electrical discharges through rarefied gases must be an essential element of every disruptive discharge, and that the phenomena of stratification might be regarded as magnified images of features always present, but concealed under ordinary circumstances. It was with a view to the study of this question that the researches by Moulton and myself were undertaken. The method chiefly used consisted in introducing into the circuit, intermittence of a particular kind, whereby one luminous discharge was rendered sensitive to the approach of a conductor outside the tube. The application of this method enabled us to produce artificially a variety of phenomena, including that of stratification. We were thus led to a series of conclusions relating to the mechanism of the discharge, among which the following may be mentioned:

1. That a stria, with its attendant dark space, forms a physical unit of a striated discharge; that a striated column is an aggregate of such units formed by means of a step-by-step process; and that the negative glow is merely a localized stria, modified by local circumstances.

2. That the origin of the luminous column is to be sought for at its negative end; that the luminosity is an expression of a demand for negative electricity; and that the dark spaces are those regions where the negative terminal, whether metallic or gaseous, is capable of exerting sufficient influence to prevent such demand.

3. That the time occupied by electricity of either name in traversing a tube is greater than that occupied in traversing an equal length of wire, but less than that occupied by molecular streams (Crookes' radiations) in traversing the tubes. Also that, especially in high vacua, the discharge from the negative terminal exhibits a durational character not found at the positive.

4. That the brilliancy of the light with so little heat may be due in part to brevity in the duration of the discharge; and that for action so rapid as that of individual discharges, the mobility of the medium may count as nothing; and that for these infinitesimal periods of time gas may itself be as rigid and as brittle as glass.

5. That striæ are not merely loci in which electrical is converted into luminous energy, but are actual aggregations of matter.

This last conclusion was based mainly upon experiments made with

an induction coil excited in a new way, viz.: directly by an alternating machine, without the intervention of a commutator or condenser. This mode of excitement promises to be one of great importance in spectroscopic work, as well as in the study of the discharge in a magnetic field, partly on account of the simplification which it permits in the construction of induction coils, but mainly on account of the very great increase of strength in the secondary currents to which it gives rise."

These investigations assume additional importance when we view them in connection with solar—I may even say stellar—physics, for evidence is augmenting in favor of the view that interstellar space is not empty, but is filled with highly attenuated matter of a nature such as may be put into our vacuum tubes. Nor can the matter occupying stellar space be said any longer to be beyond our reach for chemical and physical test. The spectroscope has already thrown a flood of light upon the chemical constitution and physical condition of the sun, the stars, the comets, and the far distant nebulæ, which have yielded spectroscopic photographs under the skilful management of Dr. Huggins, and Dr. Draper of New York. Armed with greatly improved apparatus the physical astronomer has been able to reap a rich harvest of scientific information during the short periods of the last two solar eclipses; that of 1879, visible in America, and that of May last, observed in Egypt by Lockyer, Schuster, and by Continental observers of high standing. The result of this last eclipse expedition has been summed up as follows: "Different temperature levels have been discovered in the solar atmosphere; the constitution of the corona has now the possibility of being determined, and it is proved to shine with its own light. A suspicion has been aroused once more as to the existence of a lunar atmosphere, and the position of an important line has been discovered. Hydro-carbons do not exist close to the sun, but may in space between us and it."

To me, personally, these reported results possess peculiar interest, for in March last I ventured to bring before the Royal Society a speculation regarding the conservation of solar energy, which was based upon three following postulates, viz.:

1. That aqueous vapor and carbon compounds are present in stellar or interplanetary space.

2. That these gaseous compounds are capable of being dissociated by radiant solar energy while in a state of extreme attenuation.

3. That the effect of solar rotation is to draw in dissociated vapors

upon the polar surfaces, and to eject them after combustion has taken place back into space equatorially.

It is, therefore, a matter of peculiar gratification to me that the results of observation here recorded give considerable support to that speculation. The luminous equatorial extensions of the sun which the American observations revealed in such a striking manner (with which I was not acquainted when writing my paper) were absent in Egypt; but the outflowing equatorial streams, I suppose to exist, could only be rendered visible by reflected sunlight, when mixed with dust produced by exceptional solar disturbances or by electric discharge; and the occasional appearance of such luminous extensions would serve only to disprove the hypothesis entertained by some, that they are divided planetary matter, in which case their appearance should be permanent. Professor Langley, of Pittsburgh, has shown by means of his Bolometer, that the solar actinic rays are absorbed chiefly in the solar instead of in the terrestrial atmosphere, and Captain Abney has found by his new photometric method that absorption due to hydro-carbons takes place somewhere between the solar and terrestrial atmosphere; in order to test this interesting result still further, he has lately taken his apparatus to the top of the Riffel with a view of diminishing the amount of terrestrial atmospheric air between it and the sun, and intends to bring a paper on this subject before Section A. Stellar space filled with such matter as hydro-carbon and aqueous vapor would establish a material continuity between the sun and his planets, and between the innumerable solar systems of which the universe is composed. If chemical action and reaction can further be admitted, we may be able to trace certain conditions of thermal dependence and maintenance, in which we may recognize principles of high perfection, applicable also to comparatively humble purposes of human life.

We shall thus find that in the great workshop of nature there are no lines of demarkation to be drawn between the most exalted speculation and commonplace practice, and that all knowledge must lead up to one great result, that of an intelligent recognition of the Creator through His works. So then, we members of the British Association and fellow-workers in every branch of science may exhort one another in the words of the American bard who has so lately departed from amongst us:

> Let us then be up and doing,
> With a heart for any fate;
> Still achieving, still pursuing,
> Learn to labor and to wait.

RUFUS HILL'S SPARK ARRESTER.

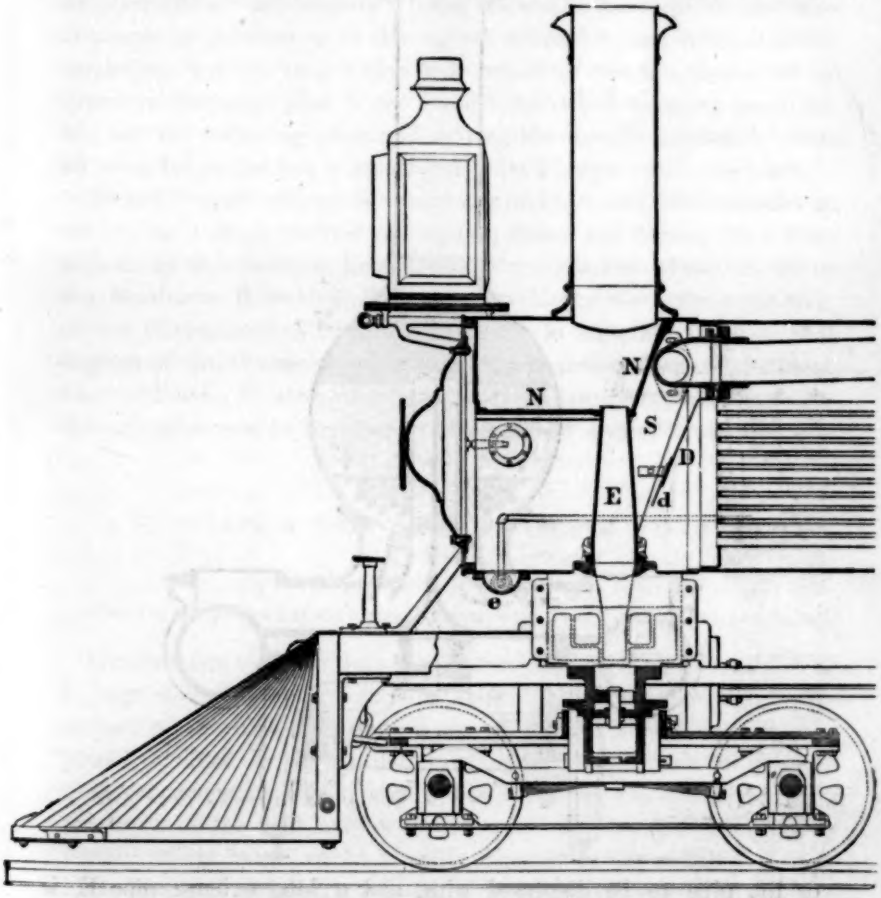
[From the report of the Secretary, November 15, 1882.]

The spark arrester, designed by Rufus Hill, M. M., Camden and Atlantic Railroad, is intended not only to prevent the escape of cinders and unconsumed fuel from the stack, but also, by regulating and equalizing the draught through the tubes, to effect a reduction in the amount of solid matter drawn from the fire-box by the action of the exhaust.

It is a recognized fact that in locomotive and other tubular boilers, the draught is materially stronger through the upper than through the lower tubes, this being due to the natural tendency of the escaping products of combustion to ascend, promoted by the higher temperature which prevails in the upper portion of the boiler. The upper tubes hence do more, and the lower less than their normal duty, and the portions of fuel which are lifted from the grate bars by the exhaust are drawn, relatively, rapidly through the upper tubes and slowly through the lower ones, tending, in the former case, to be thrown forcibly out of the stack, and in the latter, to clog the tubes. To counteract the effect of such unequal action, a deflecting plate is located by Mr. Hill in front of the flue head, and acts by checking the undue draught through the upper tubes, to proportionately induce an increased draught through the lower ones, also deflecting the escaping sparks and cinders from their natural upward course towards the bottom of the smoke box where the action of the exhaust is insufficient to overcome their gravity and carry them with the gases out of the stack. The lighter particles are arrested by a netting, the construction of which is such as to afford ample separating surface without undue increase of the volume of the smoke-box.

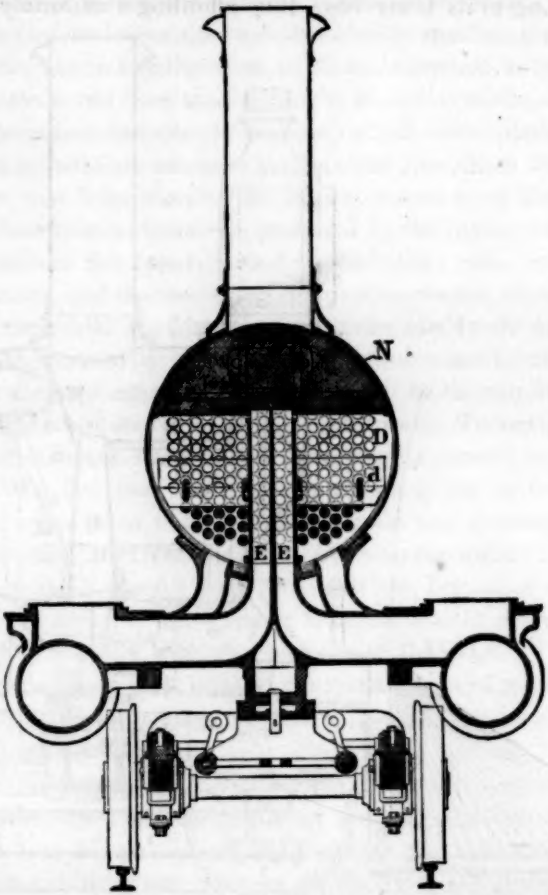
The illustrations, which are, respectively, longitudinal and transverse sections at the centre of the stack, show the improvements as applied to engines Nos. 17 and 18 of the Camden and Atlantic Railroad. These engines, which were built by the Baldwin Locomotive Works, are of the standard "American" pattern, with $16 \times 24''$ cylinders, $5'$ $6''$ drivers, and fire-boxes 9 ft. $1\frac{1}{2}'' \times 42''$ inside dimensions. (Grate surface $31\frac{9}{10}$ sq. ft.) They are adapted to burn either anthracite or bituminous coal, but have been used principally with the latter, and in service, on fast express and heavy excursion trains, their performance has been satisfactory in all particulars.

The deflecting plate D, is secured to the front flue-sheet, just above the upper row of tubes, and after projecting horizontally for such distance as to afford a space between the flue sheet and its adjacent side sufficient for the free discharge of the products of combustion from the top row of tubes, is thence inclined downwardly and outwardly from the flue sheet to its lower edge, thus affording a uniformly increasing



area of horizontal section in the discharge space formed between it and the flue sheet, in correspondence with the increasing areas of tube section presented by the several lower rows of tubes in front of which it is located. The deflector is connected at its sides to the boiler shell and smoke-box, so as to make tight joints therewith, and to admit of

such variation in the opening beneath it as may be required by differences in the duty or steaming qualities of engines, or in the character of fuel employed, an adjustable section, d, is attached to its lower side by bolts passing through slotted holes so as to be raised or lowered as desired. The use of the deflecting plate enables the usual "petticoat"



or lift pipe to be dispensed with, and a long exhaust pipe E, is employed, giving a "straight shot" exhaust into an open 16″ stack.

The netting N, which is of ¼″ mesh wire, extends horizontally across the smoke-box, from a plate at its front to the rear of the exhaust pipe, and thence is inclined upwardly, between the steam pipes S, and the lower opening of the stack, being secured to the smoke-box

by angle iron extending along its horizontal and inclined portions. A hand-hole and bonnet on the side of the smoke-box, shown in dotted lines, affords access to the lower side of the netting, and there is also an opening in the front plate above the netting, closed by a sliding cover. Cinders and unburned fuel which collect in the smoke box are blown out by a jet of steam through the ejector e, or they may be dropped into a "sub-treasury" below the smoke-box. With fire-boxes of proper proportions, as in the engines referred to, an extension of the smoke-box beyond that which will admit of the attachment of an ejector or discharge pipe, is not found to be either necessary or advisable, but the deflecting plate and netting are equally applicable where an extended smoke box is considered to be a proper spark receptacle.

The Hill spark arrester is now in use, and it is said, with satisfactory results, on a large number of engines, about 213 having been fitted with it by the Baldwin Locomotive Works, among which are 42 on the Manhattan (Elevated) Railroad, New York, the entire equipment of the Shenandoah Valley Railroad, 25 in number, together with engines of the Pennsylvania, Richmond, Fredericksburg and Potomac, Central Pacific, Western Maryland, and other railroads, and the single-driver engine sent to England by the Eames Vacuum Brake Co.

ON A NEW SWEET COMPOUND.

By CONSTANTINE FAHLBERG, PH.D.

[Abstract of a paper read at the Stated Meeting of the Franklin Institute, Jan. 17, 1883.]

GENTLEMEN:—Some time ago ("American Chemical Journal," Vol. I, page 430), in connection with an investigation upon the hydrocarbons of the coal tar group, it was discovered that a certain compound obtained by the oxydation of toluene-sulphamide with potassium permanganate tasted sweet. The sweetness was so intense that a few drops of the cold mother-liquor, remaining on and being partly washed off my hands, could be easily detected by the taste.

As soon as I had discovered this property, peculiar only to this particular mother-liquor, the substance obtained from it was subjected to several tests in order to determine whether it was poisonous to take it in larger quantities or not. At first a cat and then a dog were subjected to this cruel experiment, but they remaining fortunately alive and apparently not in the slightest degree affected by it, I decided to take

several grammes of it myself. The result was not the slightest inconvenience experienced from it. I subjected, the next morning, my urine to the chemical test, and found it to contain almost the entire quantity taken the previous night.

The compound which I now will exhibit to you forms salts with any carbonate of the alkalies, alkaline earths or metals and all of which you will find taste sweet. It is, however, not an acid, but belongs to a class of bodies which Professor Remsen and myself have given the name of "Sulphinides," the compound in question being benzoic sulphinide. It is very readily soluble in alcohol, more so than in cold water, in which it only dissolves readily when it is hot.

I am making the attempt now to prepare it in larger quantities and by cheaper methods, and have no doubt that it will find extensive use in medicine and for technical purposes.

One experiment made lately was to sweeten glucose, which as you all know tastes only faintly sweet, and the result was a complete success.

As soon as I shall have found the method by which to prepare it on a manufacturing scale I shall come before you again, and as I trust and hope, with larger samples than now, ready to give answer to all questions in regard to its price, application, etc.

Study of Atmospheric Electricity.—Among the useful applications of Mascart's electrometer, is the photographic registry of the variations in atmospheric electricity. It is necessary to maintain a perfect insulation of the different portions of the apparatus, otherwise, instead of getting a curve which represents the variations of atmospheric potential, the curve will be some unknown function of those variations and of the greater or less conductibility of the supports. Dampness, dust, spider-webs, etc., are the principal disturbances of insulation. The automatic record is made by sending a beam of light in a constant direction upon the mirror of the electrometer, which reflects it to a sensitive photographic plate moving uniformly in a direction perpendicular to the plane in which the reflected ray is displaced by the oscillations of the mirror. Since continuous observations are the only ones which take into account the varied and frequent modifications of atmospheric electricity, this method is very valuable and will doubtless lead to interesting results.—*L'Electricien*, October 15, 1882. C.

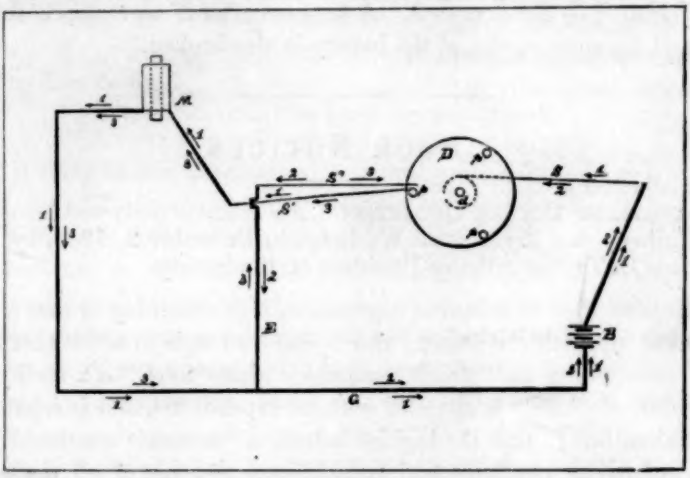
A SPARKLESS CURRENT-BREAKER.

By Louis H. Spellier.

The fact that the spark of the induced current of electro-magnetic instruments will destroy the contact surfaces by which the making and breaking of the circuit is effected, is very keenly felt on current-breakers for electro-magnetic time telegraphs.

A device for the purpose of obviating the spark, invented by Dr. Hipp, has been in use successfully for some years at Geneva, to distribute astronomical time through the different sections of that city.

The writer presents in the accompanying diagram a device of his



own for the same purpose, which, he believes, will commend itself for simplicity as well as for effectiveness.

With the exception of an additional contact spring, S″, the current-breaker is the same as described in the Journal of the Franklin Institute, August number, 1882.

The metal disk D, is fastened to the axle of the escape-wheel of a clock, and has as many platinum pins *p*, attached vertically upon its face, as there are openings and closings of the circuit needed during the time it completes one revolution. *d* is a platinum disk; fastened to the pin-bearing disk; S and S′ are two contact springs. The spring S, rests upon the platinum disk, while S′ is to make the contact with the pins *p*. When the disk moves with the escape-wheel of the clock, and

the spring S′ comes in contact with one of the pins *p*, the circuit of the battery is completed, and broken when removed from it.

In the diagram, D represents the current-breaker; B the battery; M, the electro-magnet; and G, the ground conductor. The spring S′ is in contact with a pin and thereby completes the circuit. The current now takes the course as shown by the arrows 1. The contact spring S″ is placed a little higher than S′, and therefore does not yet touch the pin *p*. But as soon as D moves on again, S″ will a moment before S′ leaves the pin come also in contact with it; at this moment S″ will make a short circuit through the conductor E, and the course of the battery current becomes that of the arrows 2, while the induced current of M, at the moment the short circuit is made, takes the course as indicated by the arrows 3. A moment after S′ leaves *p*, S″ follows it, and the short circuit of the battery is also broken.

Book Notices.

PHYSICS AND OCCULT QUALITIES. An Address delivered before the Philosophical Society of Washington, December 2, 1882, by William B. Taylor, retiring President of the Society.

In these days of scientific dogmatism, it is refreshing to find a good thinker and acute reasoner, who is bold enough to admit that there are such things as "occult qualities;" that "force" is a reality, the function of which "is attended with no expenditure, and is capable of no exhaustion;" that the highest induction "accounts consistently for the unfaltering obedience and instantaneous response of all the countless atoms of the universe to the reign of 'law,' by positing behind such law, an Infinite LAW-GIVER."

These acknowledgments are made with a degree of candor, which is as commendable as it is remarkable. It would be difficult to find, elsewhere, so concise and so fair a statement, both of the triumphs and of the insuperable obstacles of the kinematic theory, or so ready an admission that even the dynamic theory does no more than acquiesce in its results, and accepts the established properties of matter "as ultimate and inexplicable."

The conclusion (p. 36) "that matter is capable of acting *only* where it is not," diametrically opposed as it is to the old and common notion "that nothing can act save where it is," will undoubtedly strike many

readers as "absurd, incomprehensible, inconceivable" and paradoxical. It is, however, well sustained, by reasoning which may be commended to the careful study of all who are inclined to discard metaphysics and to believe that all phenomena can be explained by methods which are altogether mechanical. Mr. Walter R. Browne (*Phil. Mag.* Dec. 1880; Jan. 1883) has also adduced cogent arguments to show the necessity of granting action at a distance.

The experiments of Guthrie (1870) and Bjerknes (1881) upon attractions and repulsions by the influence of vibrations are cited, but no reference is made to Chase's earlier experiments with magnetic needles, which were published in 1864 (*Proc. Am. Phil. Soc.*, ix, 359; x, 151–66).

We note but one seeming inconsistency in the whole address (p. 48): "*Under the present system of dynamic law*, it is certain that as radiating and cooling bodies,

> 'The stars shall fade away, the sun himself
> Grow dim with age, and nature sink in years.'

Nor is there known to science any natural process whereby this cosmic doom may be either averted or repaired by exterior reversal." This is a kinematic, rather than a dynamic conclusion, and it is dynamically controverted by the fact that the velocity of light, the velocity of electro-dynamic action, and the velocity of the gravitating time-integral of solar rotation, are each equivalent to the thermal unit of velocity at the centre of our system which is indicated by Laplace's principle of periodicity (*Photodynamic Notes*, 280, 321, 333; *Proc. Am. Phil. Soc.*, vol. xx). C.

MANUAL OF BLOW-PIPE ANALYSIS AND DETERMINATIVE MINERALOGY. By H. B. Cornwall. D. Van Nostrand, 1882.

The multiplication of manuals and text-books is so great in certain branches of science that the author frequently begins his preface by apologizing for ever having written the work at all. This is the case, *e. g.*, in treatises upon qualitative chemical analysis, in manuals on geology, in ordinary school books, arithmetics, etc. But it can hardly be said to be the case in regard to works like the one we are now considering. The use of the blow-pipe in chemistry and mineralogy cannot be too greatly appreciated. The behavior of minerals, ores, and inorganic bodies in general at a high temperature, their fusibility, their reactions with fluxes, their properties in an oxidizing atmosphere, in a

reducing atmosphere, the alloys they form, their affinities for oxygen, for sulphur, their coloring power, all of these and many other properties can be determined by this little instrument with ease and certainty, and it may be stated as a fact, that whoever has thoroughly mastered the study of blow-pipe analysis must necessarily be well grounded in the principles that underlie the more important science of metallurgy, since the elements exhibit the same reactions in the small tests that they do in the large smelting works.

Mr. Cornwall's book is an octavo of some three hundred pages, containing, in practical effect, all of value to be found in Plattner's large treatise, both in qualitative and *quantitative* work. Nor is any one better fitted to abridge this standard authority than our author, since the English translations of Plattner have come from his pen.

The qualitative reactions and separations are given with great fullness and very clearly, a number of new ones being introduced. Bunsen's Flame Reactions are omitted, and without any great loss to the work, as we cannot remember ever having heard of their being used by any one other than Bunsen himself.

The system of determinative mineralogy—an important part of the work—is to a great extent new, and is excellent. We notice one or two trifling errors: the formula of Sepiolite is not correct, and the per cent. of water in Hollaysite, as given, does not correspond with its formula.* In the chapter on quantitative analysis Plattner's Chromium Assay is wisely omitted, as it is a worthless process. The Iron Assay might also have been left out with advantage since the method described is obsolete and incorrect.

We can recommend this work as being a valuable one, either to the student or to the trained mineralogist or chemist. H. P., Jr.

Vanadium Green.—The treatment of the slags which are produced in the dephosphoration of certain smeltings at Creuzot, has furnished Messrs. Osmont and Witz considerable quantities of vanadic acid. This acid is produced by the reaction of oxygen upon vanadium; on treating it with chlorhydric acid a beautiful green color is obtained, which may be employed in dyeing.—*Les Mondes*, iii, 253. C.

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* Since writing the above we have noticed several other minerals whose formulæ are incorrectly given. This is apt to lead the student astray, and is worthy of the author's attention in future editions.

ROBERT BRIGGS.

Robert Briggs was born on the 18th of June, 1822, in the city of Boston, Mass., and was educated in the public schools of that city. He early showed a special aptitude for mathematics, the use of which was to become so important in his career, and the proficiency thus acquired was maintained and increased during the whole of his subsequent life.

His technical education commenced in 1839, when, at the age of seventeen, he entered the office of Captain Alexander Parris, a civil engineer and architect of Boston and Charlestown, Mass. Here he remained for several years, partly in the capacity of pupil and partly in that of assistant, thus acquiring his first familiarity with the actual duties of the engineer. The practical education thus commenced continued uninterruptedly throughout all the following years of his life, and ranged over a broader field than it usually falls to the lot of any individual to cover with his personal experience. It included nearly all of the more important branches of work which are usually comprehended in the duties of both the civil and mechanical engineer, from the work of the surveyor in the field and in the office, to the construction of the Washington Aqueduct; from the building of a rolling mill to the superintendence of the largest tube works in the country; from the heating and ventilating of a country school-house to that of the Capitol of the United States; from the designing of steam and gas fittings to that of the heaviest pumping engines; from the draughtman's board to the editor's table. In the performance of some of these duties he occupied subordinate positions under the direction of other engineers, but in most of them he was alone, and the work done by him, whether as designer, constructor, or manager, was in the fullest sense his own. Although not an inventor in the ordinary acceptation of the term, Mr. Briggs did more new and original work than most professional inventors. In some few cases he sought protection for these fruits of his brain by patents, but most of his conceptions and inventions were given freely to the engineering public without demand for compensation and without restriction of any kind. Mr. Briggs was a disbeliever in the expediency of the patent system, or at least believed that in most fields of industrial work its provisions are unnecessary, if not actually harm-

ful. He proved his faith in this belief by giving freely the products of his own inventive powers to those who sought them, leaving the question of compensation to be afterwards adjusted or, too frequently, to be entirely neglected. This bias (or peculiarity as it certainly was) is properly attributable to his deep interest in his own work and to the spirit of professional generosity which accompanied it and which prompted him. To him it was a pleasure of the highest kind to lay before others the results of his own study and work, and this pleasure he could not forego for the mere sake of hoarding his knowledge with the prospect of possibly turning it into ultimate pecuniary benefit.

Leaving Boston in 1844, Mr. Briggs went to the West, where for a short time he taught school. Returning from the West in 1845, he found temporary occupation as a clerk in Troy, N. Y., but the bent of his mind lay too strongly in the direction of engineering for him to be long diverted from his true channel of work. According, in 1847, we find that he returned to Boston, and after a few months work under Mr. Charles Hastings, C. E., in laying out a line of railway in Massachusetts, he accepted a position as "Constructing Engineer" to the Glendon Rolling Mill, a large and important establishment then being built at East Boston. Upon the completion of that work he opened an office of his own in Boston, as Architect and Engineer, an experiment which he repeated in Philadelphia in the later years of his life. This early experiment, like the later one, met with but small success, the practice of this country in engineering matters being too strongly established upon the basis of each establishment having its own engineer, to leave room for the profitable practice of a consulting engineer, although in England this latter calling is one of the most important and lucrative in the profession.

Mr. Briggs' connection with what was to become the most important professional association of his life, commenced in August, 1848, when he entered the service of Walworth & Nason, of Boston, and assumed the charge of the building of their Tube Works and the superintendence of the same when completed. One of the surviving partners of that firm, in writing recently of Mr. Briggs, states that during this connection "he proved himself to be an able and faithful engineer, fulfilling all the duties that devolved upon him with remarkable fidelity and ingenuity. His memory is cherished with great respect and affection."

In the latter part of 1852, Mr. Briggs accepted the position of

Superintending Engineer of the firm of Bird & Weld (now the Phœnix Works), of Trenton, N. J., where he was employed in the building of machinery for the manufacture of rubber and other miscellaneous purposes. Leaving here in November, 1853, he moved to Mount Savage, Md., where for six months he acted as Superintendent of the rolling mill at that place. Six months later, in May, 1854, he exchanged this position for that of Superintendent of the well-known Renssellaer Rolling Mill, at Troy, N. Y., in which position he remained for a year.

In 1855, Mr. Briggs accepted an appointment as Assistant Engineer under Captain (now General) M. C. Meigs, in which capacity he was employed at first in the direction of the building of the Washington Aqueduct, and, subsequently, in the erection of the iron work forming the dome of the Capitol at Washington, and in the heating and ventilating of the halls of Congress. During his connection with these important works, Mr. Briggs conducted an original investigation upon the strength and proportions of cast iron pipes, and published a diagramatic table of the same. This paper, we believe, to have been the first important one of the long series which flowed from his facile pen. While engaged upon the erection of the Capitol building, he designed a lathe for turning the large monolithic marble columns which form the portico of the Capitol, and in connection with the heating and ventilating of this building, made the elaborate and original researches which were subsequently embodied in his paper read before the British Institution of Civil Engineers, in 1870.

Leaving Washington in 1857, he early in the following year became a partner in the firm of Nason, Dodge & Briggs, of New York. The senior partner of this firm, Mr. Joseph Nason, was the pioneer, in this country at least, in the art of heating buildings by steam, and in this new association, Mr. Briggs continued and enlarged the experience he had already commenced while in the employ of Walworth & Nason, as a designer and constructor of appliances for heating by steam, including the manufacture of all kinds of brass and iron fittings for the same.

It is possible that the seductions of his mathematical acquirements and his already considerable appreciation of the theoretical conditions involved in the flow of air, and other questions involved in the heating and ventilating of buildings, may have interfered with commercial success in his new undertaking, or have disturbed the relations between himself and his more practical associates, for the partnership did not continue much more than one year.

Coming to Philadelphia in 1860, Mr. Briggs entered upon the longest and, in many respects, the most important engagement of his professional life, by accepting the position of Superintendent and Engineer of the Pascal Iron Works, of Morris, Tasker & Company. These works, under his management, became the largest and most important producers in this country of wrought pipes and boiler flues, of iron and brass fittings and valves, of machinery for cutting and screwing pipes, of appliances for steam and hot water heating, and of apparatus for gas works. The works when he assumed control of them, were in a comparatively disorderly condition, and his first efforts were directed to the bringing of "order out of chaos," in which he succeeded admirably, so that the works became a model of good management and economical operation. This done, he addressed himself to classifying and systematizing the varied products of the concern, and to the preparation of an illustrated catalogue of the same. This latter, a large quarto volume filled with illustrations of the many hundreds of articles produced under his management (many of the illustrations being reproduced from his own sketches), became the standard throughout the United States for the work of the several classes to which it relates, and is to-day a monument to his untiring industry and to his comprehensive grasp of a business of almost endless detail. In 1862-63 he designed and erected large additional buildings for the Pascal Works, including a new pipe mill and machine shop, which, when put in operation, proved convenient and economical and far better than any similar plant previously erected. At about this time Mr. Briggs also designated and constructed for the city of Galveston, Texas, a flat-top gas-holder, built without interior trussing. It is believed that this method, which was a radical and bold departure from existing precedents, although it is now almost universal, was original with Mr. Briggs. Among the improvements introduced by him in the manufacture of tools for pipe fittings, was the application of the Blanchard (or eccentric) lathe to tap making, by which the "backing off" of taps was done by machinery instead of by the laborious hand process previously in use.

In January, 1866, Mr. Briggs visited England on behalf of the Pascal Iron Works, chiefly to examine the Siemens' regenerative furnace, with a view to apply it to the heating of plates in tube making. He remained abroad four months, during which time he visited most of the engineering works in England, Scotland, and Belgium. His

reception by English engineers was remarkably cordial and appreciative. His intimate familiarity with American engineering practice, in many lines of work, and his readiness to impart freely all that he knew, as well as his clear appreciation of the points in American practice which would most interest English engineers, soon brought him into pleasant and intimate relations with many of the latter and led to friendships which continued up to the date of his death. On the other hand, his life-long habits of observation and his broad acquaintance with the industrial arts gave him an interest in everything that he saw, and his retentive memory was rapidly stored with facts relating to English practice in many fields of work. The knowledge thus acquired added largely to his professional resources, and was turned to account in many useful ways after his return.

His connection with the Pascal Iron Works was the longest of his professional career, lasting nine years, or until November, 1869. At its conclusion he again visited England, remaining there nearly a year, enlarging his acquaintance with English engineers, and continuing his study of their practice, particularly in connection with tube making. It was during this visit that he presented to the Society of Civil Engineers, his paper "On the Conditions and the Limits which govern the Proportions of Rotary Fans.* This essay was a philosophical inquiry into the action of these machines, and was of great interest and value, not only in regard to the ventilating fan, but also of its analogue, the turbine. The paper was awarded a Watt medal and a Telford premium. On the 4th of February, 1879, Mr. Briggs was elected a member of the British Institution of Civil Engineers, and about this time also became a member of the Institution of Mechanical Engineers.

Returning to the United States, Mr. Briggs, in January, 1871, became the superintendent and engineer of the Southwark foundry, then belonging to Mr. Henry G. Morris. These works, previously owned by Merrick & Towne, and later by Merrick & Sons, were engaged in heavy engineering work of wide variety, and the opportunity thus opened to Mr. Briggs was, in some respects, the pleasantest and most congenial in his career. During this connection he designed and built a pumping engine, for the city of Lowell, Mass., which may be regarded as the largest single work of his life. This machine was a compound rotative engine of the "Simpson" type, with a capacity of

*Minutes of Proceedings, Inst. C. E., Vol, xxx., p. 236.

five million gallons per twenty-four hours under a head of one hundred and sixty feet. When completed it gave a "duty" of over one hundred millions, which, to those conversant with pumping machinery, is the best indication of its high qualities. In these works Mr. Briggs also designed and constructed a large variety of heavy work, including sugar mills and sugar refining machinery, gas apparatus, blast furnace engines and furnaces, stationary engines, nitrate of soda apparatus, etc. He also designed and built a large new foundry, and a thirty ton traveling crane operated by power. His engagement lasted until the closure of the works, which occurred in 1875, owing to causes resulting from the disturbance of the iron market, and wholly independent of his part in the management of the business.

For some time after the closing of the Southwark foundry Mr. Briggs was confined by illness. Recovering from this he again made a short visit to England. In 1876 he became the editor of the JOURNAL OF THE FRANKLIN INSTITUTE, which position he filled for several years, and for which his wide experience as an engineer, and his almost equal experience in the writing of papers, descriptive of engineering practice, eminently fitted him. A reference to the pages of the JOURNAL during his editorship will show how industriously he discharged his duties, and how well adapted he was to the performance of such work. His contributions were very numerous, and covered a great variety of subjects. In 1878 Mr. Briggs opened an office in Philadelphia as consulting engineer, devoting himself particularly to the designing of heavy machinery and iron work, to the application of heat in the arts, and to the designing of works for gas and water supply. His success in this experiment was only moderate for the reason, as above explained, that practice of this kind is not in vogue in this country, and obtains but little recognition and support.

In 1880 he became consulting assistant to Colonel Ludlow, United States Engineer of River and Harbor Improvements in the vicinity of Philadelphia. The terms of his engagement permitted him to retain a portion of his office practice, and he continued, until his final illness, to give more or less attention to miscellaneous engineering affairs, including particularly the heating and ventilating of large buildings. He continued also after the termination of his official connection with the JOURNAL OF THE FRANKLIN INSTITUTE to enrich its columns with contributions from his pen, and in addition to this did much other literary work. One of his papers, read before the Society of Civil Engi-

neers, of which Society he was a member, on the "Ventilation of Halls of Audience" attracted much attention. In it he urged that American engineers should discard European practice in this branch as unsuited to the conditions both of climate and physical constitution of the population; and he referred to the well authenticated fact that the modern American requires a temperature of not less than 70° F. for comfort, although his English cousins are comfortable in a room of 10° lower temperature. In 1881 Mr. Briggs presented to the British Institution of Civil Engineers an elaborate paper on "American Steam Heating Practice." Referring to this, the editor of one of our leading engineering journals writes as follows: "Although presenting few novelties to American readers it is probably the best exposition of the American system which has ever been presented to foreign engineers. In its historical details it is particularly full and valuable, Mr. Briggs having been early connected with the steam heating industry, and practically one of the first who applied scientific methods to it. To him the world is indebted for the system of pipe threads now employed, and the fittings which have practically become standard."

The foregoing outline, sketches briefly the salient points of Mr. Briggs' career as an engineer. It may be supplemented by the following tribute from a letter published soon after his death by one of his intimate friends. "One of his most notable traits was the comprehensive scope of his knowledge, which covered almost the entire field of engineering, both civil and mechanical, and included much also of metallurgy, chemistry, architecture, and applied sciences. On almost any topic under these heads he could discourse as a master, with a minuteness and familiarity astonishing to any but those who knew what an extraordinary range was covered by his personal experience in connection with mechanical and industrial operations, and who knew also how far these were supplemented by professional study and reading, continued uninterruptedly during the forty years of his business life. Added to these were the advantages of a good early education, an exceptional aptitude for mathematics (in which he excelled), and a very retentive memory. His temperament was placid and equable, and his companionship, a pleasure which his intimate friends at least can never forget."

Mr. Briggs had never enjoyed robust health, and, during portions of his life, his condition was almost that of an invalid. His vital strength had gradually failed during the latter years of his life, and in

December, 1881, after his return from a brief last visit to England, indications of paralysis developed. He continued work for some months longer, but ceased finally in April, 1882, at which time, on the advice of his physician, he left Philadelphia and went to his mother's home, in Dedham, Mass., where, on the 24th of July, 1882, he died of paralysis, resulting from tumor on the brain, after a lingering and painful illness, having just completed his sixtieth year.

Mr. Briggs' contributions to the literature of engineering were very numerous and valuable. Among them may be mentioned, in addition to the papers above referred to, his article "On the Transmission of Force by Belts and Pulleys," based on the experiments of Mr. Henry R. Towne, usually known as "Briggs' and Towne's experiments," which have been adopted in the text books both of this country and of England; a report on the "Ventilation of the House of Representatives, Washington;" a paper on the "Circulation of Water in Steam Boilers," etc.

It is to be hoped that the most valuable of Mr. Briggs' numerous papers may in time be republished in collected form, and thus made permanently available to the profession, to the advancement of which he contributed so largely during the many years of his active life.

HENRY G. MORRIS,
HENRY R. TOWNE,
B. C. TILGHMAN.

Heat and Magnetism.—L. Pilleux has lately called attention to the heating of iron during its magnetization. The fact had been previously observed by D. Tommasi in some researches which are not yet published upon the comparative study of the chemical properties of ordinary iron and of magnetized iron. In order to obtain a constant magnetic intensity he employed an electromangnet of a single branch in place of an ordinary magnet. When the current, eveh if it was produced by a weak battery, had traversed the coil for some hours, the magnetized bar became perceptibly warm. He at first attibuted the heating of the iron to the heating of the coil; but he was greatly astonished, one day when he had removed the bar in order to clean it and had forgotten to interrupt the current, to find that the coil was not heated at all.—*Les Mondes*, xxxi, 621. C.

Bleaching by Electricity.—Dobbie and Hutcheson have experimented upon bleaching by the aid of electrolysis. For this purpose the stuff is dipped into sea water and then passed through hot rolls which are connected with the poles of a galvanic battery. In order to decompose the hypochloride which is thus formed, the cloth is drawn through diluted acid and fully bleached.—*Dingler's Journal*, Oct., '82.

Gravity Barometer.—Mascart has invented a barometer in which the variations of weight are shown and measured by the changes of height in a column of mercury, which is in equilibrium with the pressure of a mass of gas. The instrument has been tested under shocks of every kind to which it would be exposed in traveling in Paris, Hamburg, Stockholm, Drontheim, and Tromsö. It was found to be readily transportable, and its precision did not appear to be inferior to that of the pendulum. It requires no other observation than that of the temperature and the level of the mercury, and the preparation can be made in less than an hour in a hotel chamber.—*Comptes Rendus*, Oct. 9, 1882, C.

Molecular Structure of Metals.—It is generally thought that the crystalline structure does not exist in metals which have been drawn or rolled. M. Kalischer has undertaken a series of experiments with cadmium, tin, copper, iron, steel, etc. He has arrived at the conclusion that the crystalline state corresponds to the natural molecular structure of metals. This state may be modified more or less easily by mechanical labor, but it is commonly reëstablished under the influence of heat. In some metals which have been drawn into wire the heat, while reëstablishing the crystalline structure, increases at the same time the electric conductibility.—*Chron. Industr.*, Oct. 19, 1882.

Light of Comets.—According to Huggins, comets emit a characteristic light which indicates, by spectral analysis, the presence of carbon, hydrogen, and nitrogen, elements which are shown by the spectra of acetylene and cyanhydric acid. Berthelot thinks that these results point to an electric origin of the light. He has shown that acetylene is formed immediately and necessarily whenever carbon and hydrogen come under the influence of the electric arc. When nitrogen is added to acetylene the electric influence produces cyanhydric acid. It seems scarcely possible to conceive of a continuous combustion in cometary matter, but an electric illumination may be easily understood.—*Ann. de Chim. et de Phys.*, Oct., 1882. C.

Use of Ethylene in Refrigerating.—Cailletet's experiments show that Ethylene is liquefied under the following pressures and temperatures:

60 atmospheres, . . .	10°C.	50°F.
56 " . .	8°C.	46·4°F.
50 " . . .	4°C.	39·2°F.
45 " . .	1°C.	33·8°F.

Its critical point is about 13° (55·4°F.), while that of carbonic acid is about 31° (87·8°F). These properties induced him to see whether liquefied ethylene would not give a more intense cold than that which corresponds to the ebullition of protoxide of nitrogen. By slightly modifying the apparatus which he used for liquefying oxygen, he succeeded in producing a more intense cold than had been previously realized. Ethylene, moreover, possesses the property of remaining liquid and transparent, under temperatures at which nitrogen protoxide and carbonic acid become solid and opaque. He hopes to obtain still greater degrees of cold by condensing gases which are more difficult to liquefy than ethylene.—*Comptes Rendus*, xciv, 1224. C.

Franklin Institute.

HALL OF THE INSTITUTE, February 21, 1883.

The meeting was called to order at the usual hour, with the President, Wm. P. Tatham, in the chair.

There were present 124 members and 39 visitors.

The minutes of the last meeting were read and approved.

The Actuary submitted the minutes of the Board of Managers and reported that at the last meeting, held Wednesday, February 14th, 7 persons had been elected to membership.

The Special Committee on "Prevention of Fires in Theatres," reported progress and was continued.

The Special Committee charged with the preparation of a memorial of the late Robert Briggs, presented a report which was read.

On motion of Mr. Hector Orr, seconded by Mr. J. B. Burleigh, the same was accepted and the Committee discharged, with the thanks of the Institute. The memorial appears in the current issue of the *Journal*.

The Secretary's report included a resume of matters of scientific interest, and an account of the following inventions:

The Pinkham Electric Gas Lighting Co.'s system of "Lighting and Extinguishing Gas by Electricity."

This is an attachment which may be adjusted to all styles of gas fixtures. It is of two forms, termed respectively the pendant and the automatic. The Leclanché battery is used to supply the electric current, and the connecting wire leading from the battery to the burners is concealed from view beneath the shell and ornamental portion of the fixture. The pendant form is provided with a light metal chain, terminated by a ball, a single pull of which turns on and lights the gas, while a second pull turns it off and extinguishes it. By the automatic form of the device, the gas is turned on and lighted or extinguised from one or several convenient points, by pressing an ivory button. By this means the gas in the hall of a house, for example, may be instantly lighted or extinguished from buttons located near the front door, at the head of the stairs, or wherever desired.

Specimens were shown of "Terra Cotta Lumber," made by the Terra Cotta Lumber Co., of New York. This material is used for fire proof construction of every description in architectural work, and is said also to be well adapted for filters, underground electrical insulation, steam boiler and pipe sheathing, fire lighters, imperishable ground sills, waterproof brick, grain and elevator bins, refrigerators, safe and vault linings, fireproof jackets for iron columns, furnace linings, safety warehouses, etc. The material from which it is made is clay mixed with resinous saw-dust. It is prepared into various shapes by passing through dies, allowed to dry, then baked at an intense heat in a kiln. The saw-dust burning out leaves the burned pieces porous. It may be planed, tongued, grooved, sawed, etc., into any desired shape.

The "Boiler Setting" of the Rich—Morrison Perfect Construction Company was also described and illustrated by lantern views. The object of the invention is to effect a more complete combustion of carbonaceous fuel and to suppress the smoke nuisance. This is sought to be accomplished by the admission of steam and air into the fire space in a peculiar manner. A special description of this device is in course of preparation for publication. Louis H. Spellier's "New Sparkless Current Breaker" was illustrated and described. This device is described in this number of the JOURNAL.

B. Frank Teal's "Portable Sectional Elevator and Projector," designed